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THE EFFECTS OF PLANTING DATES AND POTASSIUM, NITROGEN
AMENDMENTS ON GROWTH, DEVELOPMENT, AND
YIELD OF DRY BEAN
(*PHASEOLUS VULGARIS* L.) GENOTYPES

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By

Tara P. Nepal

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ABSTRACT

THE EFFECTS OF PLANTING DATES AND POTASSIUM, NITROGEN AMENDMENTS ON GROWTH, DEVELOPMENT, AND YIELD OF DRY BEAN (*PHASEOLUS VULGARIS* L.) GENOTYPES

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An experiment was conducted to investigate the effects of planting dates and potassium and nitrogen amendments on the development and yield of dry bean genotypes. Twelve dry bean genotypes were planted at almost weekly intervals commencing the 19 May 1978. Potassium and nitrogen supplements were made at planting, and at bloom stage of crop development.

Significant effects of planting dates were observed for all of the parameters investigated in this study. Also, significant genotypic differences were evident. With the exception of percent plant stand, pods per plant and seeds per pod, significant planting date x genotype interactions were observed. Certain genotypes had significantly higher plant height at physiological maturity, pods per plant and seeds per pod with additional fertilizer application than with normal rate. No significant planting date x fertility levels interactions were observed. Except for seedling emergence at 7 days after planting, no significant planting date x fertility levels x genotype interactions were apparent.

Excluding seedling emergence and percent plant stand, the 15 June planting resulted in the poorest growth and yield contributing parameters. Most genotypes included in this study exhibited superior vegetative growth, relatively longer developmental period, higher seed yields and

yield components at the two earliest plantings than at the two latest plantings. This is attributed to increasing intensity of environmental stresses with the progress of the growing season, which was experienced by the plants sown on the two later plantings during the critical stages of their vegetative and reproductive development. Advancing dry bean planting to the second half of May may result in substantial gains in seed yields.

To

My Parents

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INTRODUCTION

Dry beans rank second among all cash crops grown in Michigan and production generates about $120 million in annual revenues. Between 8-10 thousand farmers are involved in growing Michigan's dry beans on about 210,000 hectares. Michigan accounts for 33% of the colored beans, 95% of the white navy class of beans and 34% of the total dry edible beans produced in the United States. Average dry bean yields throughout the United States have remained static while Michigan yields have shown a downward trend during the past twenty years. (U.S. Department of Agriculture, 1977. Agricultural Statistics Government Printing Office, Washington, D.C.). In addition to declining yields, Michigan's share of the national dry bean production is also declining. Such long-term trends are cause for concern among growers, shippers and researchers.

Growth, development and productivity of crop plants result from a complex of interactions between genotypes, environments and management practices. Realization of the yield potential of a crop requires the optimization of environmental conditions and management practices which are in harmony with the needs of a particular crop at specific periods of growth and development. Recently large scale successes in obtaining maximum yields of several crop species has resulted from an integrated approach towards development of genotypes which are better suited to existing environmental conditions in a particular locality; and which are more responsive to rapidly improving technologies.

Investigations designed to study the response of genotypes to different environmental variables either under controlled or field conditions enable one to define the optimum environmental parameters required by a plant at its different stages of growth and development. Attempts to optimize environmental conditions for field grown plants by adjusting the planting date is one way of enhancing crop productivity. In addition planting date studies conducted in conjunction with various levels of management inputs could lead to more precise timing and amount of costly fertilizer inputs.

Attempts have been made to obtain increased dry bean yields in Michigan through better management practices involving the use of more precise management inputs. (Robertson and Frazier, 1978). Despite these efforts, no substantial increase in bean yields has been obtained under current production practices. In addition to yield reductions caused by diseases, insects and stresses of edaphic and climate origin. Michigan's short growing season can further limit commerical production. Planting too early reduces seedling emergence, retards seedling growth and development and predisposes plants to attack by soil borne pathogens. Hence, bean growers generally plant the first week in June when the soil is sufficiently warm to permit satisfactory emergence and seedling growth.

Dry bean yields are positively correlated with amount of increase in photosynthetic rate from flowering to pod set (Peet et al., 1977). Lucas, Milbourn and Whiteford (1976) have demonstrated the importance of photosynthesis during the pod filling stage. The fact that a major contribution to bean yields seems to be from photosynthesis and translocation from the leaves (Appadurai & Rajakaruna, 1976) underlines the need for adjusting planting dates so that optimum leaf area development is in phase with maximum solar radiation, thereby insuring higher photosynthetic efficiency for a larger duration during the pod filling stage.

Despite the obvious advantages accruing from more favorable environmental conditions during the postflowering period of an early planted crop, it is likely to suffer from poor plant stand due to adverse soil temperature and moisture conditions in initial stage of crop growth and development. Delayed planting in an attempt to avoid plant losses from adverse soil conditions can result in exposure of plants to less favorably environmental conditions during the postflowering period which in turn can lead to yield reductions. Besides the losses associated with a restricted growing season a late planted bean crop in Michigan is likely to suffer considerable loss from the cold, wet weather conditions that frequently prevail at the time of harvesting.

Additionally, low yield in grain legumes has been attributed to decline in photosynthetic activity of leaves due to translocation of Nitrogen from vegetative tissues to the developing seeds due to declined nodule activity during the pod filling stage. (Sinclair & DeWit, 1975; 1976; Sinha, 1973; 1974). Rivero and Giraldo (1976) have reported declining nodule activity in *Phaseolus vulgaris* L. at the onset of pod filling stage. Though response to potassium fertilization by *Phaseolus vulgaris* L. is dependent on past soil treatment and level of soil potassium and a negative response is frequently reported (Eira, 1974; Asif & Grieg, 1972), additional potassium was sidedressed at planting time in view of the dependence on potassium in order to obtain profitable response from higher rates of nitrogen application. (Munson, 1970). Works on soybean by Odurukwe (1973) and Chevalier (1978) reveal the favorable effect of potassium on seed yield while that of Chesney (1973) emphasizes the need for higher levels of potassium with increasing levels of nitrogen application.

No conclusive experimental evidence is available regarding the optimum date to plant dry beans in Michigan. Moreover, little information exists as to the performance of dry bean cultivars planted at different dates under Michigan environmental conditions. This investigation was conducted to evaluate the effects of varying the sowing date from mid-May to mid-June on the growth, development and yield of several classes of dry beans. Specific objectives were to:

1. Investigate the effects of planting dates and potassium amendments on seedling emergence and plant density of 12 dry bean genotypes representing different commercial classes.
2. Investigate the effects of planting dates and potassium and nitrogen amendments on growth and development of 12 dry bean genotypes representing different commercial classes.
3. Investigate the effects of planting dates and potassium and nitrogen amendments on yield and yield components of 12 dry bean genotypes representing different commercial classes.
4. Compare the performance of colored and white seeded genotypes in each planting date and at each fertility level.
5. Compare the performance of colored and white seeded isolines at each planting date and fertility levels.

LITERATURE REVIEW

SECTION 1

EFFECTS OF PLANTING DATES ON DEVELOPMENT AND YIELD OF SOME GRAIN LEGUMES

Differential response of crop cultivars to planting dates result from the changing of environmental conditions encountered by plants started at different dates. Changes in daily atmospheric temperatures and humidity, soil temperatures, day length, precipitation, evapotranspiration and solar radiation associated with varying dates and exposure of different stages of a developing crop to such environmental variables determines the rate and pattern of crop development and final productivity.

1. Common Beans (Phaseolus vulgaris L.)

The germination, emergence, early growth and final plant stand of beans is dependent on soil temperature and moisture conditions. Harrington (1963) reported that germination was slight when soil temperature was below 15°C. He also reported slower growth of seedlings of the slow gerninating seedlings. Stakonov (1976) has reported an increased rate of germination of bean seeds is associated with increasing temperature from 18-42°C.; the germination time for all cultivars tested being longest at 18°C. Planting date studies conducted in the United Kingdom suggest optimum sowing for navy beans around mid-May when soil temperatures at 10 cms. depth have reached 12-13°C. Earlier sowing has been found to reduce plant establishment (Scarisbrick, Car & Wilkes, 1976; Scarisbrick & Wilkes, 1973), However, significant genetic variability exists among genotypes for their ability to germinate and develop under suboptimal soil conditions. In addition, inherent seed characters such as seed coat color, seed size and initial moisture content of the seeds appear to exert great influence on the ability of bean seeds to germinate and develop under cold, wet soil conditions. Harwick (1972) has reported that small seeded cultivars of French and Runner beans emerged better at low temperatures; but the size of the seedlings was reduced under these conditions. Villiers, Nel and Hammes (1974) observed that cultivars with large and medium sized seeds germinated more slowly than those with small seeds and germination rate increased with an increase in temperature. Austin and Maclean (1972a) have shown marked effects of temperature and seed size on seedling weight of common bean.

Deakin (1974) working with near isogenic lines of Phaseolus vulgaris differing only in seed coat color observed a significantly higher emergence and seedling vigor in color seeded sublines than in their white seeded counterparts. Moreover, the yields from the colored seeded lines were 67% higher than their white isolines. Dickson (1971) observed an association between seed coat color and resistence to decay to soil organisms with ability to germinate at low temperatures (8-10°C). However, a low percentage of white seeded lines were reported to have had good germination and decay resistance. Wyatt (1977) working with four near isogenic lines of snap beans reported higher permeability of white seed coats to water than colored seed coats in response to an osmotic gradient with subsequent cracking and susceptibility to attack by soil pathogens. He also reported a negative correlation between seed coat thickness and seed coat dry weight and the rate of osmosis through seed coats.

Pollock, Roos and Manalo (1969) showed that temperatures lower than 15°C coupled with low oxygen supply adversely affect the emergence and vigor of garden bean seedlings. This was especially true when seeds were imbibed at low moisture content, less than 12%. The stress conditions increased the number of decaying seeds and decreased seedling size and number of normal seedlings. Roos and Manalo (1976) observed that bean seeds with initial moisture content greater than 12% had higher field emergence than seeds with lower moisture content particularly when the soil temperatures were below 10°C. Scroth, Weinbhold and Hayman (1966) and Hayman (1968) observed a positive correlation between percentage damping off of seedlings by root rot organisms and the amount of seed exudates which increased at temperatures below 18°C and above 30°C.

Abellan, Vives and Chacon (1977) found a positive correlation between dry bean seed yield and solar energy and temperature and a negative correlation with rainfall and humidity. Rauseo, Vives and Chacon (1975) found positive correlations between seed yield and evaporation, solar radiation, maximum, minimum and average temperatures variation and sunshine. Negative correlations were reported between rainfall duration and humidity. Ojeda, Vives and Chacon (1974) observed that the highest yield corresponded to low cumulative values of rainfall at flowering and high amounts of sunshine up to 70 days after sowing. In their study yields were correlated with temperature and radiation but not with humidity.

Schroder (1973) reported that early May sowing of beans in Germany resulted in a relatively longer developmental period, which was shortened by later sowings until about the 20th of June. The period was prolonged further by still later sowings. Hardwick (1974) reported smaller seedlings at emergence from beans planted early than from those planted later. This observation was due to the effect of low temperature during germination. The same author (1973) has reported decreased fresh pod yields in dwarf French beans at low temperatures because of a reduction in the number of pods initiated at auxillary branches. Low temperatures are found to reduce pod yields by directly affecting the growth of auxillary buds.

Dale (1965) has demonstrated the dependence on temperature of leaf surface expansion, rate of leaf unfolding from stem apex and partitioning of dry matter between the leaves and the rest of the plants. Low temperatures (10-12°C) were found to reduce photosynthetic efficiency of dry beans which was thought to be due to reduction in leaf chlorophyll content (Narikawa & Muira, 1974). Similar results have been reported by Austin and Maclean (1972b). Izhar and Wallace (1967) have shown a reduced net CO_2 uptake for several hours of two-week-old _Phaseolus vulgaris_ L. plants kept overnight at 10°C. Crookston et al. (1974) have reported that plants kept overnight at 5°C exhibited severe reduction in photosynthesis the following day. Observations by Dale (1964) emphasizes the importance of constant temperatures during the growing season since final dry weight and leaf area were greatest at constant temperature and least where the temperature fluctuated.

Lakhanov (1975) has reported that low temperatures (3-5°C) occurring for a 4 day period during seed germination, flowering, seed formation and seed swelling stage had adverse effects on plant survival, rate of development and yield. Similar results were obtained when Haricot beans were exposed to low temperatures for 7 days at various stages (Lakhanov, 1973). However, Kemp (1973) showed genetic variability in beans for tolerance to low temperatures during initiation and development of flowers. Best results on growth, flowering, fruiting and yield of snap beans were obtained by Singh and Mack (1966) when soil temperatures were around 25°C.

Atmospheric temperatures prevailing during the reproductive stage of Phaseolus vulgaris L. appear to be of vital importance in terms of final productivity. In addition to exerting influence on length of the preflowering phase, atmospheric temperature affects the duration of flowering, the percent pod set and time to physiological maturity. Enriquez (1975) had reported a high correlation between night temperature and days to first flower. His data shows that by increasing the temperature (18-27°C) and day length (9-16h); a small reduction in number of days from sowing to first flower occurred in both sensitive and insensitive lines. However, the main factor controlling the time to first flowering was temperature in the insensitive lines and day length in sensitive lines. Similar results have been reported by Enriquez and Wallace, (1974). Padda and Munger (1969) have shown that under suboptimal conditions, further development of floral primordia is delayed or completely inhibited even though flower initiation occurs.

Villiers, Nel and Hammes (1974) studied the effects of day/night temperatures of 35/25°C, 30/20°C and 25/15°C on the development of eleven dry bean cultivars under controlled conditions. The number of leaves, total leaf area and dry root weight/plant were greatest at 30/20°C.

Root growth was very sensitive to high temperatures (35/25°C) during the early growth stages but during flowering top growth was more seriously affected than root growth. The number of flowers/plant and percentage pod set were generally highest at 30/20°C. Villiers (1975) observed that day/night temperatures of 32/18°C for a 7-day period during the flowering stage retarded flowering while exposure to this temperature during the flower bud or early flowering stages extended the flowering period, increased the number of flowers/plant and delayed maturity of the first pods. Flowering and pod set were most adversely affected when plants were exposed to high temperatures for a longer period from the 14th to 56th day after sowing. Seed yields were decreased only when plants were exposed to high temperatures after 49 to 56 days from sowing.

Mack and Singh (1969) observed reduced percent pod set and weight of pods of bush French beans when plants were subjected to high temperatures during the blooming period. They have reported up to 65% yield reduction due to maximum temperature of 28-38°C. Using white pea beans, Davis (1945) concluded from his studies that approximately 57% of the blossoms set seeds if the maximum temperature did not exceed 24°C. For each degree above 24°C, he reported a reduction of approximately 2% in the set of pods. Smith and Prayor (1962) observed that under high temperatures a reduction in the percent of flowers that set seeds and number of beans/pod occurred.

Soil moisture conditions during the growing season have dramatic effects on bean growth, development and seed yield. Excessive soil moisture during emergence and early growth aggravates the activity of soil borne pathagens promoting plant losses. Tsiklauri (1975) obtained high yields by maintaining soil moisture content at 70% of field capacity.

Dimitrov (1975) has also reported that the best root development in Haricot beans occurred when soil moisture content was maintained at 70% of field capacity. Miranda and Belmer (1977) reported significantly reduced pods/plant, 1,000 seed weight and seed yield because of soil moisture stress during vegetative, flowering and from pod development to maturity. Megalhaes, Millar and Choudhary (1978) have concluded the flowering stage is the most critical period for water stress. These authors reported significant reduction in seed yields and pods/plant due to moisture stress, but the number of seeds/pod was not affected.

Conflicting results exist in the literature concerning the effects of soil moisture stress on growth, development and seed yields of beans. Dreibrodt (1952) found a reduction in seed yields when water was withheld in the vegetative phase of pot grown beans. In three field experiments Gableman and Williams (1960) found a response to irrigation in the vegetative phase even in the presence of rainfall. Maurer, Ormord and Scott (1969) found a yield reduction associated with a 32% available soil moisture level before flowering. However, Kattan and Fleming (1956) reported no yield reduction when the crop received neither rainfall nor irrigation in the vegetative phase so long as the soil moisture was adequate during the rest of the season. Bierhuizen and de Vas (1959) found that when water stress during the vegetative phase was severe enough to cause stunting of growth, it still did not reduce yield as long as there was a plentiful water supply during flowering.

Salter and Goode (1967) quote numerous workers who reported on improved seed yield resulting from irrigation during the flowering and pod development phase. Kattan and Fleming (1956) showed a yield reduction from 22.91 to 16.56 ton/ha if water was withheld in the flowering phase, and down to 6.51 ton/ha if water was withheld during the pod development. Robins and Domingo (1956) found a yield reduction of about 20% when moisture stress persisted for 15 days prior to blooming, 18-22 days if it occurred during blooming or 15 days before ripening. Stoker (1974) concluded that dwarf bean seed yields were reduced the most when water stress coincided with flowering. Yields were also reduced by stress during both the early and late vegetative phases. A stress during early or late pod development had no effect on yield. Stoker (1974) reported yield reduction mainly in the form of a smaller number of pods/plant arising from flower abscission and mortality of young pods. However, the number of seeds/pod was slightly less though individual seed weight was little affected by water stress. This author showed a reduced straw yield if stress occurred either during flowering or both early and late vegetative phases.

2. Soybeans [*Glycine max* (L.) Merr.]

Rapid and uniform emergence of soybean seedlings in the field has been recognized as one of the key factors in obtaining maximum soybean yields. Went (1961) concluded that less than optimum levels of temperature or moisture may weaken the seed and render it more susceptible to other factors in the seed environment and consequently reduce emergence. Soybeans have been found to have the fastest rate of germination and emergence between 25 and 35°C (Edwards, 1934; Delouche, 1953; Hatfield & Egli, 1974). Shupert (1971) observed a higher germination percentage in the growth chamber at 27/21°C temperature regime than at 21/16 or 16/10°C regime. However, Fehr, Burris and Gilman (1973) reported no consistent effect of soil temperature on the percent emergence of the cultivars they studied.

Grabe and Metzer (1969) reported that soybean cultivars differed in their hypocotyl elongation when subjected to temperatures near 25°C. Gilman, Fehr and Burris (1973) also studied hypocotyl elongation (a potential indicator of germination and emergence) of various cultivars when grown at temperatures of 20-32°C at 1°C increments. They found that hypocotyl elongation of the short hypocotyl cultivars was not inhibited at 20 or 30°C, but was at intermediate temperatures (maximum inhibition at 25°C). The long hypocotyl cultivars exhibited no such inhibitation between 21 and 29°C. Burris and Knittle (1975) have suggested that some inhibitor or inhibitor precursor may be located in the cotyledons of the short hypocotyl cultivars that causes the reduced hypocotyl elongation at 25°C.

Seed size is known to have profound influence on germination and emergence. Some studies have indicated that smaller soybean seeds have faster germination rates (Edwards & Hartwig, 1971) and higher total laboratory and field emergence percentages (Green et al., 1965). Singh, Misra and Mehta (1978) reported that germination was negatively correlated with 100 seed weight, seed volume and thickness and weight of seed coat indicating that germination is decreased in the larger seeds and in those with hard seed coats. However, Burris, Edge and Wahab (1973) observed a moderate to substantial reduction in the emergence percentage for the smaller seed (particularly the smallest seeds) for three of the four cultivars they studied. Other studies (Fontes & Ohlrogge, 1972, Singh, Tripathi & Negi, 1972; Johnson & Leudders, 1974) have reported essentially no effect of seed size on the field emergence percentage.

Littlejohn and Tanner (1976) observed cultivar differences in the germination and emergence rates of 10°C; however, no cultivar differences were noted at 20 and 30°C. Hopper, Oberholt and Martin (1979) observed decreased time required for 50% emergence (18.8 - 4.0 days) as the temperature increased from 10 to 30°C. They found slower germination rate of smaller seeds than that of larger seeds. Besides significant cultivar x temperature interactions on germination and emergence rates, they also observed that most cultivars merged in terms of germination and emergence rates at temperatures between 10 and 20°C and at the higher temperatures the cultivar rankings were different from those observed at temperatures below the merging point.

Obendrof and Hobbs (1970) reported that sensitivity to chilling injury of soybean seeds depends upon initial moisture content at the time of imbibition. Imbibition of low-moisture soybeans at 5°C was reported to cause a reduction in seedling survival, dry matter accumulation and seedling height. They reported reduced survival of low moisture (6%) seeds but not of high moisture seeds (16%). Injury in soybean may occur after thirty-six hours of imbibition. Bromlage, Leoplod and Parrish (1978) concluded that low temperature interferes with normal membrane organization during imbibition probably by modifying the physical state of membrane phospholipids and that the consequent abnormal organization of membranes is a basic cause of low temperature injury. Thomas, Miller and Hill (1975) reported that low temperature during imbibition significantly reduced stands due to preemergence damping off caused primarily by *Pythium ultimum*.

Lawn & Byth (1973, 1974) have concluded that responses in the duration of phasic development patterns in soybean cultivars were related to changes in day length and temperature regime during each phase. The duration and extent of vegetative development for the various cultivar planting date combinations were closely associated with the length of the period from planting to the cessation of flowering. Vegetative growth was greatest for those planting dates which resulted in a delay in flowering and/or extended the flowering phase.

Osler and Cartter (1954) reported that the earlier varieties gave highest yields when planted at May 15; late varieties gave highest yields when planted about May 1, and a variety intermediate in maturity gave maximum yields when planted either May 1 or May 15. Maturity date of later maturing varieties was affected less by delay in planting than was that of the genetically earlier varieties. Feaster (1949) found that for maximum yields short season varieties should be planted somewhat later than long season varieties. Weiss et al. (1950) reported that their earliest variety did not differ significantly at various planting dates while yield of the latest variety decreased progressively with dates subsequent to May 1. They reported that maturity of genetically early varieties was retarded more by delay in planting than the of later varieties.

Decreased day length is reported to have resulted in fewer days to maturity and shorter plant height (Hartwig, 1970; Huxley & Summerfield, 1974; Huxley, Summerfield & Hughes, 1976; Johnson, Borthwick & Leffel, 1960; Lawn & Byth, 1973; Whigham, 1975; 1976). Cultivars classified as early maturing show little response to decreased day length, but those classified as late maturing will flower and mature in fewer days when grown in short day environment (Criswell & Hume, 1972; Johnson, Borthwick & Leffel, 1960; Lawn & Byth, 1973). Leffel (1961) reported that flowering and postflowering phases in soybeans were shortened by delayed planting and attributed this response to shorter day length. Abel (1961) found that delayed planting reduced the time for 50% flowering to maturity in early maturing cultivars, whereas the preflowering phase was shortened in late maturing cultivars. Both phases of development were shortened by delayed planting in cultivars of medium maturity. Hartwig (1954) also reported a marked decrease in the preflowering period for late planting of early cultivars. Lawn & Byth (1973) have shown that variation in the length of period from flowering to maturity takes place primarily during the flowering phase. Day lengths which favor late flowering also favor long flowering periods. Similar results have been reported by Whigham, Manor and Carmer (1978). Johnson et al. (1960) reported that the exposure of plants in the flowering phase to photoperiods longer than those preceeding flowering have resulted in longer flowering and flowering to maturity periods.

Lawn and Byth (1973) reported a significant effect of temperature on the number of days to flower and on the number of days to maturity only for those cultivars least sensitive to photoperiod. Major et al. (1975) reported that under conditions of more rapidly changing temperature and day length, these environmental variables were additive in their effects on flowering. Temperature has a greater effect than day length on plantings made before 1 June at latitudes from 37 to 44°N. After that day length had a greater effect; short days caused larger reductions in the number of days to maturity than did cool temperature. Brown (1960) and Hartwig (1970) reported delayed flowering at temperatures below 25°C regardless of day length. Brown (1960) also reported maximum rate of development between planting and flowering at 30°C. Lawn and Byth (1973) reported significant negative correlations of length or preflowering phase with both the mean maximum and mean minimum temperatures for the third week period prior to flowering.

Sierra (1977) has reported that the contribution to progress towards flowering of a daily amount of solar radiation is higher when daily photoperiod is photoinductive than when daily photoperiod is nonphotoinductive. Cahpurina (1972) reported correlations ranging from -0.78 to -0.92 between the temperature conditions of early plant development and the length of the growing period from emergence to seed maturity. The reduction in the length of the whole growing period was mainly due to a reduced period of flowering, the duration of which was determined to a considerable extent by the temperature during the preceeding stage. Whigham, Minor and Carmer (1978) reported that differences in the length of complete life cycle were due more to the influence of the environmental variables on the number of days to flower than on the number of days from flowering to maturity. They also reported that management variables affected the number of days from flowering to maturity more than did environment.

Roberts and Stuckmeyer (1939) found that flowering of two soybean cultivars was inhibited by low temperatures. Garner and Allard (1930) attributed year to year variation in the number of days from planting to flowering at any one planting date to variations in temperatures during the preflowering phase. Flowering was consistently delayed by low temperatures at the beginning and the end of season. Lawn and Byth (1973) concluded that photoperiod was the dominant factor influencing the response of planting date in the length of preflowering phase for most cultivars. The effects of temperature were clearly observable only for the earliest cultivars which were effectively day netural in the photoperiod range they examined.

The length of preflowering phase occupies a vital role in soybean seed yields. Hague et al. (1966) found that yield was influenced by the length of the bean growth period and the number of reproductive nodes which was closely related to the length of the preflowering period. Hanway and Weber (1971) associated yield with the length of the bean growth period and concluded that major yield differences between varieties and years were due to differences in the length of this period. Laing (1974) demonstrated a nonlinear relationship between soybean yield and the length of the preflowering period when a sufficiently wide range of varieties were considered within a particular environment. Jones and Laing (1978) observed that the duration of the preflowering phase shows a direct effect on node numbers and hence a parabolic effect on yield whereas the duration of pod filling has linear effect on yield.

Lawn and Byth (1974) reported that, in general, physiological development proceeded more rapidly and the number of days from planting to the beginning and to the end of flowering period was reduced with delayed planting and genetic earliness of maturity. The decline in seed yield paralleled the occurrence of insufficient vegatative growth to permit the formation of closed canopies. Jones and Laing (1978) reported highly significant effects of temperatures on bean number per reproductive node. Warmer conditions during flowering could be expected to facilitate pod set and ovule development thus increasing bean numbers. The temperature and radiation receipts during the flowering and pod filling stages are dependent on the dates of commencement of these stages and thus are linked to the duration of the previous stages. Since temperature plays a critical role in pod set, the timing of flowering assumes critical importance. They also reported influence of temperature during flowering on subsequent bean growth rate. They postulated that temperature conditions during late flowering might influence early ovule growth in such a manner as to affect subsequent bean growth rate.

Temperature extremes, low radiation intensity and water stress increased the rate of flower and pod abortion (Shaw & Laing, 1966; Mann & Jaworski, 1970; Saito et al., 1970) while supplemental radiation and high CO_2 levels reduced the rate of flower and pod abortion (Johnston et al., 1969; Hardman & Brun, 1971). Increased percentage of flower and pod shedding due to high temperature (32°C) and long photoperiod were reported by Van Schaik and Probst (1958); though cultivar differences were evident. Huxley and Summerfield (1974) reported that high night temperature (24°C) hastened flowering and offset the increase in number of days to flowering caused by a long photoperiod. Huxley, Summerfield and Hughes (1976) reported that high night temperatures (24°C) promoted early vegetative growth and induced early flowering while high day temperature (33°C) caused reduced yield per plant.

Besides affecting the response of soybeans to photoperiod (Parker & Borthwick; 1973) an increase in night temperature for certain cultivars of soybeans has been found to decrease the number of days to flowering, but as the plant matures an increase in day temperature decreases seed yield (Summerfield, Bunting and Roberts, 1975). Thomas and Raper (1976; 1977; 1978) have concluded that temperature plays a critical role in controlling plant morphology as well as pod-to-flowering ratios. Thomas and Raper (1978) have emphasized the interacting effects of temperature, photosynthate and nitrogen availability since temperature has a marked influence on pod appearance rate, pod number and pod dry weight. Runge and Odell (1960) reported that mean maximum temperature and precipitation from 25 June to 20 September explained 60% of the variability in Illinois soybean yields. Thompson (1970) found that highest yields in the central U.S. were associated with temperatures which were higher than normal in June but lower than normal in July and August.

Natochieva (1979) observed a positive correlation (r = 0.65) between the amount of rainfall between flowering and seed development and yield. Doss, Pearsen and Rogers (1974) concluded that adequate water at pod filling stage was critical for obtaining highest seed yields. Thompson (1978) reported that peak demand for soil moisture coincided with the end of flowering to pod filling. Approximately 25% yield decrease has been reported by Buntley, McCutchen and Morgan (1973) when evapotraspiration exceeded rainfall during pod filling. Naylor, Teare and Nickell (1975) have reported that water stress in soybeans lowered photosynthetic rates, reduced shoot growth and yield and hastened maturity. Sionit and Kramer (1978) reported that stress during flowering induction caused abortion in some flowers. Water stress at early pod development caused greatest reduction in number of pods and seeds while stress during pod formation and pod filling caused greatest reduction in seed weight. Constable and Heron (1978) reported that soil water deficits during pod filling in soybeans caused early leaf death and cessation of pod filling thus decreasing seed yield. Burch, Smith and Mason (1978) reported that in addition to yield reductions by 35% maturity was hastened in rainfed crops in comparison to irrigated crops.

Sivkumar and Shaw (1978) reported close correlation between rate of leaf area expansion and soil water potential. Bunce (1978) has reported reduced leaf expansion rates and net photosynthetic rates per unit leaf area because of moisture deficit. Blonchet, Gelfi and Bosc (1977) have reported linear relationship between dry matter production and water use. The dependence of seed production on water use and seed total dry:matter ratio prompted them to advocate the selection for cultivars with moderate leaf area, a strong root system and a high seed:total dry matter ratio of dry conditions.

3. Cowpeas [Vigna unguniculata (L.) Walp]

Atmospheric temperatures during the growing season exert profound influence on development and seed yields of cowpeas. Huxley and Summerfield (1976) showed that small changes in aerial temperatures can have a drastic effect on seed yield. They further concluded the possbility of the role of temperature in determining 'rates' and 'duration' of seed growth. Summerfield, Minchin and Roberts (1978) investigated the overall effect on the duration of seed growth of warmer compared with cooler day and night temperatures under controlled conditions in a glasshouse. They reported an average reduction of 25% in the warmest regime. Summerfield (1973) reported that warm day tempetatures accelerate the rate of leaf senescence in cowpea as well as promoting considerable abortion of peduncles, flowers and young pods.

Huxley and Summerfield (1974) reported that night temperature also affects responses to day length and may even be more important in determining flowering time and seed yield. Summerfield, Wien and Minchin (1976) reported that many cultivars flowered earlier in the shorter day length, sensitive cultivars flowered up to 28 days sooner in warmer than in cooler nights. In several instances, the effects of longer day length in delaying flowering and of warmer nights in hastening it, almost exactly offset one another so that time to first flower under the extreme treatment combinations were closely similar. Although differences in day temperature between 27 and 33°C have hardly any effect on the onset of flowering of the cultivars investigated by Summerfield (1975) warmer day temperatures markedly decrease seed yields in cowpeas. Increased abortion of peduncles, flower and young pods, together with accelerated leaf senescence, can negate yield potential created by maximum node production before the onset of flowering (Summerfield, Wein and Minchin, 1976).

Roberts et. al. (1978) concluded that very warm temperatures are deleterious to seed production in cowpea because they decrease not only seed number per fruit but also individual seed size (by decreasing the rate of accumulation without increasing the duration of fill). They reported that differences in day temperatures (27 to 33°C) had hardly any effect on the duration of vegetative growth whereas cool nights (19 to 24°C) delayed the appearance of first flowers by an average of 4.5 days. The longest peduncles were produced in the coolest day/night temperature regimes (27/19°C); warm days decreased peduncle length by 25% and warm nights by 37% so that peduncles were less than half as long in the warmest day/night temperature regime (33/24°C). Plants grown in 33/19°C day/night temperature regime were 14% shorter, unbranched, had nodulated less well and produced smaller roots and less leaf tissues. These vegetatively inferior plants weighed 25% less than plants in other treatments. The mean dry weight of individual seeds contained in the first fruit produced in the 27/19°C day/night temperature regime was more than double that recorded in the warmest regime (33/24°C). This was attributed to longer duration of linear phase of increase in dry weight accompanied by higher rate of increase in seed dry weight during the linear phase. Furthermore, fruits maturing in the cooler day temperature regimes contained the largest number of seeds, followed by warm days with cool nights (33/19°C) followed by the warmest day/night temperature regime (33/24°C).

Soil temperature also affects the growth, development and yield of cowpeas. Philpotts (1967) reported a linear decrease in nodulation and total dry weight with increasing soil temperature (at sowing depth) from 31-40°C. Lal (1974) found that soil temperatures between 30-34°C were optimum for seedling growth. Minchin, Huxley and Summerfield (1976) reported that mean maximum soil temperatures above 32°C significantly reduced vegetative growth of cowpea cultivars, through their effects on branch, peduncle and root dry weight per plant and to a lesser extent on leaf production. The warmest temperature regime (35-40°C) also reduced nodule activity. Seed yields were adversely affected due largely to changes in the number of peduncles/plant as mean maximum soil temperature increased from 25.8 to 35.4°C.

4. Fababeans (*Vicia faba* L.)

Simons (1974) reported that seeding of fababeans when seedbed temperatures are lower than 10°C is likely to cause delayed germination and reduce the number of plants established. Brouwer (1964) found that the rate of leaf expansion in broad beans increased between root temperatures of 10 and 20°C, but remained constant between 20 and 30°C. Suboptimal soil temperatures (less than 20°C) reduce dry matter production. Keatinge and Shaykewich (1977) reported that low soil temperatures in the initial vegetative growth may be responsible for failure to achieve potential crop crowth.

Atmospheric temperature has a strong influence on growth and development of fababeans. Bull (1968) reported that the relative rate of increase of leaf area per plant was closely related to daily maximum air temperature. El-Nadi (1969) observed a higher relative growth rate in broad beans at 24°C than at either 18.5 or 29.5°C. Evans (1957) reported that maximum growth rate of fababeans occurred between 23 and 30°C, but varietal differences were evident. Hodgson (1967) reported maximum relative growth rate in field beans at the highest mean temperature experiences in their study (14-16°C). Listowski, Jackowska and Wirowski (1966) suggested that high night temperatures (20°C) might reduce seed yields in field beans but the influence of this variable was much less important than that of moisture stress. Ishag (1973) reported up to 23% reduction in seed yields because of hot dry weather between rains. Keatinge and Skykewich (1977) reported that high ambient temperature (above 20°C) appear to be deleterious to crop growth.

Sprent, Bradford and Norton (1977) reported that variations in growth were associated wtih variation in soil moisture content. They suggested that water supply may be a more important factor controlling yield than either solar radiation or plant competition, with the period following pod setting being specially vital. They reported that at the time of pod setting water requirement may often be in excess of supply. Karamanos (1978) reported that drought hastened the senesence of older leaves and increased the number of dead leaves per plant. In addition to inducing early leaf death water shortage effectively controls total active leaf area by controlling leaf production and leaf unfolding. Keatinge and Shaykewich (1977) reported that high soil moisture stress appears to be capable of severely reducing yields especially when experiences during the early phases of reproductive development. El-Nadi (1969, 1970) found that the imposition of water stress at flowering resulted in a considerable increase in flower shedding and that the effect of water stress on seed yield was most severe at the time of seed setting.

Soil moisture stress can retard growth of broad beans and water stress greatly reduces absolute leaf growth (Elston et al., 1976). Jones (1963) found that seed yield in field beans depended on rapid growth before the flowers began to develop and that an early check to growth by drought could not be corrected by plentiful supply of rain at later stages of growth. The importance of rapid early growth has been demonstrated by Paulsen (1977) who observed a significant and positive correlations of the number of nodes before flowering with duration of preanthesis growth, number of pods per inflorescence, number of seeds per pod and the efficiency of seed production. Ishag (1973), in an attempt to identify the physiological factors affecting seed production of broad bean, demonstrated the need for a large leaf area duration before flowering and large leaf area at podding nodes for higher seed yields.

Lawrie and Wheeler (1975) concluded that yield limitations in broad beans could result from suboptimal Carbon or Nitrogen fixation from an imbalance between the two processes since Nitrogen fixation is dependent on a ready supply of photosynthate. Sprent (1972) and Pankhurst and Sprent (1975) reported that water stress may affect nodule activity directly while Huang, Boyer and Vanderhoef (1975a, 1975b) reported indirect affect of water stress on nodule activity via a reduction in supplies of photosynthate. El-Beltagy and Hall (1974, 1975) reported that the abscission of reproduction organs in broad beans is influenced by ethylene concentration which may vary with water stress. Lambeth (1950) and Kambal (1969) have concluded that abscission of buds, flowers and young fruits is accentuated by unfavorable environmental conditions which include low humidity, high temperature and low soil moisture.

5. Peas (Pisum sativum L.)

Pea yields vary greatly depending on location, planting date and year. A large part of this variation in yield has been attributed to highly variable weather conditions during the growing season. Several investigators have reported that air temperature has a predominant influence on the growth and yield of peas. Bosewell (1926) planted peas at weekly intervals and thereby exposed them to progressively higher temperatures. Later plantings required less time to reach any particular stage of development but higher temperatures had an adverse effect on pod set, though there was no reduction in number or weight of peas per pod with later plantings. In his further work Bosewell (1929) found that closest inverse relationship between high temperature and yield was for the period between blossoming and harvest. Experiments by Karr, Linck and Swanson (1959) reveal the existence of a relatively well defined thermal sensitive period with maximal sensitivity to high day temperatures occurring at about 9-11 days after full bloom, and maximal sensitivity to high night temperatures occurring Lamber and Linck (1958) for a period lasting from 5 days before to 15 days after full bloom reduced fresh weight and seed size. Exposure to 32°C reduced yield more effectively than exposure to 29°C, while 29°C was more effective than 27°C. High temperature exposure of plants for 6 hours during the light period reduced yields according to number of exposures, five consecutive daily exposures being more deleterious than one. They reported that the most critical period was five days after bloom.

Bosewell (1926) reported that pea yields fell rapidly with aerial temperatures, yield decreases being attributed mainly to decreased number of pods per plant. In general, most workers have shown that yields are reduced by high temperatures above an optimum temperature of approximately 16-21°C. Fletcher et al. (1966) concluded that growth decreases below and above an optimum value near 20-21°C and dry weight, peas per pod and pea yield all decrease when air temperatures are above the optimum. They observed that where temperatures exceeded the optimum for most growth characteristics, the mamimum temperature was negatively correlated with vine and pea yield, whereas where temperatures were suboptimum to optimum, the mean maximum temperature was positively correlated with vine and pea yield. Adedipe and Ormord (1970) also reported reduced growth and yield under growth room conditions when day temperatures were raised from 20 to 30°C, night temperatures were raised from 13 to 21°C or soil temperatures lowered from 18 to 10°C.

Karr, Linck and Swanson (1959) distinguished between effect of day and night temperatures following anthesis when he reported a yield reduction of 25% from high night temperature (day of 32°C with 15 v/s

30°C night) and yield reduction of 8% from high day temperature (night 30°C with 24 v/s 32°C day). Stanfield, Ormord and Fletcher (1966) attempted to determine relative effects of day/night temperatures on development of peas where soil moisture were not limiting. They concluded from a growth room experiment that optimum temperature for total vine growth shifted from 21/16°C to 16/10°C (day/night) during the course of plant development and that yield of peas decreased at a temperature above 16/10°C.

Mack (1973) reported that maximum vine weight occurred at the seasonal mean daily soil temperature of 17.5°C (20 cms. depth) when moisture stress was kept low. The weight was less at lower (10.4°C) and at higher (29.2°C) soil temperatures. They reported maximum yields at the coolest temperatures and that reduction occurred with increased soil temperatures. They reported considerable growth and yield reduction because of moisture stress. Wang (1960) indicated that the combination of a warm spring (during the seedling stage) and a cool summer (during the reproductive period) produces a high yield while the combination of a cold spring and a hot summer produces a low yield. Based on yield records for several years, he found that an average of over 25% of the yield figures were correlated with mean temperature differences between these two significant growth periods (Wang, 1962). Milbourn and Hardwick (1968) attributed reduced yield in late planted peas to fewer podding nodes/main stem, fewer pods/podding node and a slower rate of increase in pod weight.

SECTION II

EFFECTS OF NITROGEN FERTILIZATION ON GROWTH DEVELOPMENT AND YIELD OF SOME GRAIN LEGUMES

Nitrogen fertilization of grain legumes has been an issue of great curiosity in the past several years. Response of nitrogen fertilization by legumes appears to be dependent on native soil nitrogen, soil organic matter, previous cropping history, weather conditions--primarily rainfall during the growing season, rate of nitrogen applied, time and form of fertilizer used. However, differential response of genotypes to nitrogen fertilization have frequently been obtained. In general, nonnodulating lines seem to have benefitted from higher levels of nitrogen application while nodulating lines do not appear to have responded well to additional doses of nitrogen.

I. Common Beans (*Phaseolus vulgaris* L.)

De Souza (1969) from Kenya reported that *Phaseolus vulgaris* L. can fix adequate N to meet its nutritional requirements. However, results from several other studies do not support his findings. Sistachs (1970) has reported 32% increase in seed yields with application of 90 Kgs N/ha, though he observed reduction in nodulation. His study indicated that both N fertilization and inoculation are necessary to obtain a high seed yield with high N content. Castro and Perera (1975) obtained significant increase in the number of pods/plant and the weight of 100 seeds with Nitrogen application. Roberts and Weaver (1970) observed a significant yield response with application of 179.2 kgs N/ha. The additional N is reported to have significantly delayed maturity besides promoting vegetative growth. They did not report any detrimental effects of high N fertility under suitable weather conditions.

Wilkes and Scarisbrick (1974) reported significant yield response to 125 kgs N/ha resulting from an increased number of pods/unit area. Failure to observe any advantage from further increase in N level was attributed to lower than average precipitation during the growing season. Asif (1970) has also reported increased pod yields with Nitrogen application.

In snap beans, Doss, Evans and Turner (1977) have reported increased rate of plant growth and final plant height with N fertilization. However, the effects were mainly between non N and the lowest N rate used in their study. Asif and Greig (1972) obtained increased bean yields with application of 67.2 kgs N/ha at planting and 2 weeks after emergence. However, they reported a nonsignificant decline in yields with application of 201.6 kgs N/ha parcelled at 2 equal dressings. El-Leboudi, Maksoud, and Midan (1976) reported significantly increased number of pods/plant with application of 50 kgs N/ha 24 days after sowing than with no nitrogen treatment. Works by Smittle (1975) and Doss, Evans and Turner (1977) underscore the importance of irrigation in order to obtain increased bean yields with high levels of N fertilization.

Also, attempts have been made to increase bean yields through split application of N fertilizers during vegetative growth of dry beans. Montjos and Megalhaes (1971) succeeded in obtaining increased dry bean yield through fractional application of 66 kgs N/ha at 3 equal dressings--7, 14 and 21 days after emergence. This procedure is reported to have delayed leaf senescence and improve the photosynthetic capacity of the crop because of increased leaf area duration. However, Mascarenhas (1966) failed to observe any favorable effect of such split applications, through application of 50 kgs N/ha significantly increased seed yields.

One of the most recent developments towards obtaining increased yields in grain legumes has been the concept of nitrogen fertilization during the reproductive stage of the crop. Works by Sinclair and De Wit (1975, 1976); Lindoo and Nooden (1976); Derman, Rupp and Nooden (1978) on soybeans and by Sinha (1973, 1974) on several grain legumes indicate that low yields in grain legumes could result from decline in photosynthetic activity during the pod filling stage accruing from translocation of N from vegetative tissues to the developing seeds since the disintegrating nodules are unable to meet the N requirement of the plant during this period. Gallo and Miyasaka (1961) observed greatest uptake of N by Phaseolus vulgaris L. at the period of seed development in the pod. They suggested the desirability of delayed N application since plant requirements at this stage may not be satisfied by N fixation alone; and it would not interfere with the early steps of symbiosis. This concept is in general agreement with Rivero and Giraldo (1976); Graham and Rosas (1977, 1978) and Bethlemfalvy and Phillips (1977) who have reported highest levels of N fixation in Phaselous vulgaris L. at flowering with a decline in nodule activity thereafter.

Franco, Pereira and Neyra (1979) have reported 59% increase in seed yields with application of NH_4NO_3 to the soil at flowering. Papanicolau, Skarlou and Apostolakis (1977) have reported slightly increased yields with application of N fertilizers two weeks before flowering than with application at sowing, but yields were decreased by delaying fertilizer application until the end of flowering. Oliker, Polajkoff-Moyber and Mayer (1978) have suggested the possibility of enhancing bean seed production by delaying N fertilization until the third week after anthesis. However, Lauer (1979) failed to observe any significant effect of foliar applied N and some other nutrients during reproductive period of the crop.

2. Soybeans [Glycine max (L.) Merril]

Soybeans derive N directly from the soil as inorganic residuals or as mineralized organic soil fractions and indirectly by the symbiotic nodule relationship where the bacterium Rhizobium japonicum fixes N present in the soil atmosphere. Investigations by Allos and Bortholomew (1959); Harper, Nicholas and Hageman (1972) and Weber (1966a, 1966b) indicate that the amount of N fixed symbiotically range from 25-75% the total soybean nitrogen.

Nitrogen fertilization has offered inconsistent yield responses of soybeans and has been reported to have detrimental effects on nodule formation or bacteria efficiency concurrent with a decrease in symbiotically fixed nitrogen (Allos & Bartholomew, 1959; Bhangoo & Albritton, 1976; Ham et al., 1975; Harper & Cooper, 1971; Hatfield et al., 1974; Lyons & Early, 1952; Sorensen & Penas, 1978; Thorton, 1947; Weber, 1966a, 1966b). Sistachs (1974) reported that primary nodule production was adversely affected by N application. Bezdick, Mulford and Magee (1974) reported decreased N fixation with increasing rate of N application though there was a significant increase in dry matter, nutrient uptake and yield. Abu-Shakra and Bassiri (1972) reported inhibited nodulation with increased nitrogen availability. Posypanov (1974) reported that N application delayed nodule formation by 7-14 days.

Ludwig and Allison (1935) proposed that variation in C : N gradient during nitrogen assimilation was responsible for the change in the reaction of the legume plant to nodule bacteria. In the presence of low nitrogen, soybean plants contain an excess of carbohydrate, some of which is secreted by the roots into the rhizosphere where it stimlates the growth of microorganisms (Hatfield et al., 1974; Hughes &

Metcalfe, 1975; Richardson, Jordan & Garrard, 1957; Van Schreven, 1962; Weber, 1966). However, with increasing N concentration, the plant carbohydrate may be tied up on the protein forming process to such an extent that there is little if any carbohydrate excreted from the roots into the rhizosphere (Richardson, Jordan & Garrando, 1957), resulting in little inducement for the bacteria to be attracted to the plant roots. The role of root secretions on multiplication of effective rhizobial strains have been demonstrated by Rovira (1956) and Stewart (1966).

However, there are a considerable number of literature reviews on behalf of inadequacy of nitrogen fixation by the rhizobia living symbiotically on soybean plant roots to meet the needs of the plants (Harper, 1974; Harper & Hageman, 1972; Hatfield et al., 1974; Howell, 1963; Lathwell & Evans, 1951; Loos & Louw, 1965; Weber, 1966). Many investigators (Fuehring & Finkner, 1974; Groneman, 1974; Hera, 1974; Hulpai, 1973; Lathwell & Evans, 1951; Rios & Dos Santos, 1973) have emphasized the importance of some combined nitrogen in obtaining maximum yield. Their yield of soybean was closely correlated with the amount of nitrogen accumulated throughout the life cycle of the plant. Grain yield was determined by the number of pods and subsequently by the number of seeds retained by the plant, and this was determined by the levels of nitrogen during the bloom and seed filling period.

Positive yield responses of soybeans to nitrogen fertilization are associated with decreases in the amount of N fixed during later growth stages due to nodule senescence (Lawn & Brunn, 1973; Weil & Ohlrogge, 1972) or competition between nodules and seed formation for plant assimilates (Blomquist & Kust, 1971; Lawn & Brunn, 1974). Norman and Krampitz (1945) observed that nodulated soybeans did not make maximum dry weight yields when relying throughout the life cycle predominantly on nitrogen fixation to supply total nitrogen needs of the plants. In experiments carried out by Kang (1975) fixed nitrogen was adequate to supply the nitrogen needs of the crop, but 30 kgs N/ha was needed with inoculation for maximum yields. Similar results have been reported by Hatfield et al. (1974) and Sorensen and Penas (1978). Early supplies with small amounts of mineral nitrogen enable the plant to maintain a reasonable growth rate from the outset. This may cause more rapid plant growth and root development which would then prepare more sites for nodule production (Allos & Bartholomew, 1959; Hatfield et al., 1974; Howell, 1963; Orcutt & Wilson, 1935; Shibles, Anderson & Gibson, 1975; Van Schreven, 1959; Harper & Hagemen, 1972; Shibles & Weber, 1966; Terman, 1977).

Maximum utilization of nitrogen by the soybean plant occurs during the later growth stages (Harper, 1971; 1974; Hendersen & Kamprath, 1970). In an analysis of photosynthate and nitrogen requirements of 24 different crops, Sinclair and De Wit (1975) reported that grain legumes have the higher nitrogen requirements per gram of photosynthate, soybeans having the highest N requirement (29 mg/gm of photosynthate) of all crop species examined. The high demand for N during seed development and inability of the soil N and symbiotically fixed N to meet this demand require translocation of N from vegetative tissues to the rapidly developing seeds. Rapid translocation of N from leaves in the form of amino acids resulting from degradation of proteins, especially ribulosebiphosphate carboxylase, and enzyme which comprises 25% of the protein in soybean leaves and which is responsible for photosynthetic CO_2 fixation leads premature senescence of the leaves, thus curtailing the duration of seed development (Sinclair & De Wit, 1975; 1976).

Similar results have been reported by Derman, Rupp & Nooden (1978) and Lindoo and Nooden (1976) on soybeans and Sinha (1973; 1974) on several grain legumes.

Based on the data of Hanway and Weber (1971), Sinclair and De Wit (1976) calculated that 130 kgs N/ha can be supplied by vegetative organis (assuming minimum N concentration in vegetative organs at maturity) to the developing seeds. Translocation of N at the estimated rate of 5 kgs N/ha/day from vegetative tissues results in depletion of the supply and self destruction after a seed growth period of only 26 days. They have concluded that since the main source of variability in seed yield is the duration of the seed development period, either an increase in N supply rate from the roots or an increase in stored nitrogen within the vegetative plant lengthens the seed development period and increases seed yields.

Several workers have reported that 50-64% of the nitrogen in soybean seeds comes from redistribution of N from the vegetative portions of the plant during the filling period (Borst & Thatcher, 1931; Hammond et al., 1951; Hanway & Weber, 1971b). Latimore, Giddens and Ashley (1973) reported that demand for N at the pod filling stage was high, 23% of the total being required during a period of 20 days from mid to late pod filling stage, when nitrogen fixation by nodules was declining. High N requirement during the phase of seed development stems from much N needed for duplication of both genetic and protoplasmic proteins.

The high demand for N during seed development of soybean requires timing of fertilizer application in such a way that maximum uptake of applied N occurs at the critical stage of reproductive development. Mederski et al. (1958) and Enken (1959) reported better responses of N applied at the beginning of flowering. Shibles and Weber (1966) reported that limited N supply at full bloom or pod and seed setting resulted in abortion of potential storage sites. They emphasized the need of N for production of storage proteins during bean filling. Iwata and Utada (1967) reported that a lack of N for 2-3 weeks immediately before flowering reduced yield, while withholding N after flowering had no effect on yield. Brevedon, Egli and Legget (1978) applied 168 kgs N/ha at the beginning or end of flowering or both to field grown soybeans. Markedly less effect was obtained with N applied late than with that given early and increased seed yield resulted from increased number of seeds/plant mainly and also due to increased seed weight. Conversely, Welch et al. (1973) reported no effect of application of up to 224 kgs N/ha at plantings or sidedressed at early flowering or pod filling.

Popescu and Axinte (1979) reported that application of 64 kgs N/ha at pod formation stage gave highest seed yields as compared to the treatments receiving the same quantity of N at the vegetative stage or at the flowering stage. Rios & Dos Santos (1973) reported that application of 60 kgs N/ha at flower initiation increased soybean seed yields by 325 kgs/ha. Nodule number and weight were unaffected by N at 40 or 60 kgs/ha but 120 kgs N/ha retarded nodulation, the N affecting mean weight of nodules formed shortly after its application. Deibert, Bijeriego and Olsen (1979) applied N fertilizer at rates of 45, 89 and 134 kgs/ha at planting or at full bloom. Nitrogen fertilization had no effect on seed yield of nodulating isoline, but increased the seed yield of nonnodulating isoline due to delayed fertilizers application. Fertilizer utilization percentage of both lines at later growth stages increased as fertilizer rate increased. Fertilizer applied at planting at rates above 45 kgs N/ha reduced the symbiotically fixed N fraction, whereas delaying fertilizer application had no such influence at any rate of N employed.

Further clarification on nitrogen status of soybean plants have been obtained through studies conducted in hydroponic growth conditions. Streeter (1978) reported that withdrawal of N only 30 days prior to maturity resulted in major reduction in seed size and seed nitrogen concentration. Nitrogen stress during reproductive stages reduced seed yield to nearly 25% of the control and only when N stress was prolonged was additional N exported from leaves and stems. Lathwell and Evans (1951) grew uninoculated soybeans in a nutrient solution containing 100 mg N/liter. When N was withdrawn from the solution during flowering, seed yield was decreased four-fold relative to plants which received 100 mg N/liter until maturity. Harper (1974) reported that NO_3 utilization was highest at full flowering with symbiotic N fixation reaching its peak 3 weeks later during pod filling. Seed yields of plants totally dependent on N were 50% less of those using both NO_3 and atmospheric N under hydroponic growth conditions. Egli, Legget & Duncan (1978) reported that increasing the supply of N to the plant during the filling period had no effect on maturity or on the amount of nitrogen redistributed to the seed in comparison to the control suggesting that the redistribution of N from the vegetative material to the seed can't be prevented by increasing the N available to the root system. This finding is in general agreement with that of Hanway and Weber (1971a), who reported that the redistribution of nutrients, including N, from vegetative material to soybean seed occurred regardless of the rate of fertilizer application. They concluded that nutrients are translocated to the seed from vegetative material even though readily available in the soil.

Also, attempts have been made to investigate the possibility of obtaining increased soybean yields through foliar fertilization during the seed filling stage. Garcia and Hanway (1976) reported increased seed yields of soybeans with 2-4 foliar applications of 80:10:24:4 kgs N:P:K:S per hectare during the seed filling period, yield increased being attributed to increased number of seeds and not seed size. They postulated that the uptake of nutrients from the soil and their rate of translocation through the xylem is not adequate to supply the requirements of the soybean plants in order to avoid the normally observed depletion of these nutrients from the leaves during the seed filling period. Paradoxically, Boote et al. (1978) failed to observe increased soybean yields with five weekly foliar sprays of 28:2.9:8.4:1.2 kgs N:P:K:S per hectare primarily because it did not meaningfully enhance leaf N or photosynthetic rate of photosynthetic duration. Robertson, Hinson and Hammond (1977) also failed to observe increased soybean yields through foliar fertilization.

3. Cowpeas [*Vigna unguniculata* (L.) Walp]

Nutman (1971) reported that annual symbiotic fixation of field grown cowpea plants has been variously estimated at between 73 and 240 Kgs N per hectare. Depending on the effectiveness of the cowpea-rhizobium symbiosis various responses of cowpeas to Nitrogen fertilization are likely. Nangju (1973) reported that with effective nodulation and symbiosis cowpea yields were not increased by applied N fertilizers up to 180 Kgs N/hectare. These findings substantiate other field experiments in the tropics on a range of cultivars (Summerfield et al., 1974). However, Worley et al. (1971) and Johnson and Evans (1975) reported significant increases in cowpea seed yields in response to N applications ranging from 40-600 Kgs/ha.

Rachie and Rockwood (1973) reported that effectively nodulated cowpea plants gain little or no benefit in terms of seed production from nitrogen fertilization. Experiments with pot grown plants of cowpea in glasshouse environments showed that small amounts of applied N at sowing (equivalent to 30 Kgs/ha or less) could benefit symbiotic fixation, but higher levels of N were detrimental (Dart & Mercer, 1965). Of course, soil may contain available nitrogen equivalent to these values so that further N fertilization would then be detrimental. Eaglesham et al., (1974) reported that adding combined N to nodules which are already fixing can have deleterious effects. Alternatively, small doses of applied N may be synergistic and stimulate nodule production and symbiotic fixation in cowpeas (Pate & Dart, 1961; Ezedinma, 1964; Dart & Wildon, 1970) and even improve seed yield (Summerfield et al, 1976).

Summerfield et al. (1977) reported that although symbiosis supplies over 80% of the plants N content throughout growth, maximum rates of fixation are achieved by this association at about the time plants come into first flower and subsequent values decline markedly during the rapid pod fill. Englesham et al. (1977) also reported maximum fixation rates at flowering with subsequent decrease during pod development. Although the daily N fixation rate during fruit maturation was equivalent to only about 25% of the average value during early fruit growth, it was slightly greater than that calculated for the entire vegetative period. Minchin et al. (1977) reported that in higher yielding cowpea rhizobium associations rates of symbiotic fixation equivalent to 33% of the maximum recorded soon after flowering had been measured just 5 days before all the pods were mature.

Eaglesham et al. (1977) demonstrated that maximum rates of N assimilation occurred during pod fill, with nodules contributing ten times more nitrogen than the applied source. Symbiotic fixation contributed significantly to seed N during late pod fill, when nutrient N assimilation was negligible. Vegetative N content was greatest at mid pod fill, and mobilization of this pool was equivalent to 44% of total seed nitrogen. Summerfiled et al. (1977) reported that the nitrogen supply to cowpea seeds seems to depend largely upon postflowering symbiotic fixation and/or uptake of inorganic nitrogen. In their experiments, although nodulated plants receiving no applied nitrogen had the most rapid rate of fixation they were smaller vegetatively and in seed yield compared with nodulated plants receiving a low level of nitrogen throughout the growth period. They suggested application of small quantities of inorganic nitrogen in order to maximize early vegetative growth and hence optimize subsequent seed yields. Dart et al. (1977) demonstrated that irrespective of the amount and/or time of N application, nodulated cowpea plants produced almost 40% greater seed yields than nonnodulated ones. Nonnodulated plants relying on N produced fewer branches, peduncles and mature pods. They also reported that adding nitrogen after flowering delayed leaf senescence and/or encouraged continued leaf production besides increasing individual seed weight and number per pod. However, seed yields were not significantly increased by N applications to nodulated plants. Summerfield et al. (1976) also reported that seed yields of effectively nodulated plants were almost double those of nonnodulated ones regardless of differences in the timing and level of inorganic N applied. They also reported little effect on seed yields of short-term applications of fertilizer N on cowpea although only levels up to 60 ppm N were applied.

4. Fababeans (_Vicia_ _faba_ L.)

Fababeans require large quantities of N to attain full yield and protein potential. McEwen (1970) reported that 4820 Kgs/ha fababean seed contained 229 Kgs N/ha. Richards (1977) reported that the production of a 2000 Kgs/ha fababean seed yield containing 30% protein required 194 Kgs N/ha of which 116 Kgs N/ha was contained in the seed and 78 Kgs N/ha was contained in the straw and roots.

Rogalsky (1972) and Sadler (1975) reported that N broadcast at the surface significantly increased fababean seed yields, suggesting that symbiotic N fixation was not fully able to satisfy the fababean's requirements. Kralova and Mouchova (1974) reported that maximum aerial yield of fababeans harvested at flowering occurred when 105 to 210 mg K/ha soil had been applied at seeding. They also observed that fababeans receiving the higher rates of N fertilizer had fewer nodules than those receiving no supplemental nitrogen.

Some researchers have suggested that fababeans are capable of fixing all of their nitrogen requirements. McEwen (1970) reported that rates of N fertilizer broadcast on the surface at seeding in excess of that which could be symbiotically fixed resulted in seed yield increases of less than 10% with protein content being unaffected. Split N applications and single large midseason N applications also did not effect seed yield and protein content. In identical growth chamber experiments with _Pisum_ _arvense_, _Pisum_ _sativum_ and _Vicia_ _faba_ researchers reported that single large N applications at the onset of flowering significantly increased aerial yields of *P. sativum* and *P. arvense* but had no effect on *Vicia faba*. They concluded that these fababeans derived sufficient N from symbiotic fixation (Rinno, Ebert & Wildner, 1973) and Richards and Soper (1979) concluded that fababeans when nodulated with effective strains of Rhizobia obtain their N from soil and symbiotic fixation, which was able to fully satisfy fababean's N demand throughout their entire growth cycle. Aerial yield was not affected by N fertilizer up to 200 mg N/ka soil applied at seeding, by 100 mg N/kg solid applied in four fractions nor by single midseason applications of 100 mg N/kg soil. Only the highest rate of N employed (300 mg N/kg soil) at seeding significantly increased fababean yield, the increase being 13.2%. They also reported that fababeans were capable of fixing substantial amounts of N after pod fill, amounting to a least 28% of the total seasonal symbiotically fixed N. However, a significant linear inverse relationship occurred between fertilizer N uptake and symbiotic N fixation. Increasing quantities of fertilizer uptake into fababean tissues decreased plant N derived from fixation.

MATERIALS AND METHODS

Dry Bean genotypes used in this study were grown in a nursery during the summer of 1978 at the Crops and Soil Science Research Farm, located south of the Michigan State University Campus. Seeds were precision drilled with a modified air planter into four row plots. Rows were 4.8 m long spaced 50.8 cms apart. Each row was planted with 48 seeds. The design was a split-split plot with four replications.

The four planting dates - May 19, May 27, June 7 and June 15 - were the whole plot treatments. The sub-plot treatments consisted of a recommended rate of fertilizer (N, P, K) based on soil tests at planting and a potassium and nitrogen ammendments applied at planting and at early bloom, respectively. The sub-subplot treatments consisted of 12 dry bean genotypes representing several commercial classes and were variable for growth habit and maturity. A description of the genotypes used in this study are as follows:

1. Black Turtle Soup: A black seeded commercial dry bean genotype obtained from the Michigan Crop Improvement Association. Seed was produced in Michigan during the 1977 crop year.
2. Rico-23: A bulked pure line black seeded accession similar to Black Turtle Soup for seed and growth characters. Seed was maintained by the Michigan Agricultural Experimental Station and was increased by M. W. Adams during the 1977 crop year.

3. Ex-Rico-23: Bulked pure line accession maintained by the Michigan Agricultural Experiment Station. This accession was suspected by breeders to have arisen as a white seed coat mutant from Rico-23. Seed was increased by M. W. Adams during the 1977 crop year.
4. Aurora: Small white seeded commercial variety obtained from the William Muller and Sons Seed Company, Vassar, Michigan.
5. Viva (Pink): Bulked pure line varietal material representative of the Sutter's Pink Commercial class. Maintained by the USDA Vegetable Crops Production Research Unit. Prosser, Washington. Seed was obtained from D. W. Burke and was increased during the 1977 crop year.
6. Viva (White): A white seeded mutant extracted from Viva (Pink). Maintained by the USDA Vegetable Crops Production Research Unit. Prosser, Washington. Seed was obtained from D. W. Burke and was increased during the 1977 crop year. Viva (White) and Viva (Pink) are isolines differing only in seed coat characteristics. Comparisons should provide information on the effects of seed coat color on seedling emergence and subsequent growth.
7. Sanilac: Commercial certified seed of the navy class obtained from the Michigan Crop Improvement Association. Seed was produced in Michigan during the 1977 crop year.
8. Seafarer: Commercial certified seeds of the navy class obtained from the Michigan Crop Improvement Association. Seed was produced in Michigan during the 1977 crop year, and is the earliest maturing dry bean genotype.

9. Tuscola: Commercial certified seed of the navy class obtained from the Michigan Crop Improvement Association. Seed was produced in Michigan during the 1977 crop year.
10. Strain No. 20489: Commercial certified seed of the navy class obtained from the Michigan Crop Improvement Association. Seed was produced in Michigan during the 1977 crop year.
11. P.I. 165426 (White): A plant introduction characterized by small, flat white seeds and maintained by the USDA, Vegetable Production Research Unit, Prosser, Washington. This accession is a Type IV (climbing type) with respect to growth habit. Seeds were obtained from M. J. Silbernagle.
12. P.I. 165426 (Black): A plant introduction characterized by small, flat black seeds and maintained by the USDA, Vegetable Production Research Unit, Prosser, Washington. This accession is a Type IV (climbing type) with respect to growth habit. Seeds were obtained from M. J. Silbernagle. P.I. 165426 (Black) and P.I. 165426 (White) are isolines differing only in seed coat color. Comparisons should provide information on the effects of seed coat color on seedling emergence and subsequent growth.

Prior to planting a herbicide mixture consisting of Lasso [2-chloro-2', 6'-diethyl-N-(methoxymethyl) acetanilide] and Amiben [3-amino-2,5-dichlero bezoic adic] was applied at the rate of 2.2 and 1.7 Kgs/ha respectively. A mixed fertilizer consisting of 0-20-20 and NH_4NO_3 that yielded 45, 30, 30 Kgs/ha N, P_2O_5 and K_2O respectively was applied in rows at planting based on the soil test results of the composite sample obtained from the experimental site prior to planting. The chemical analysis of composite soil sample showed 10 KgsNHa, 55 Kgs P_2O_5/Ha and 134 Kgs K_2O/Ha. The soil pH was 7.6

Since initial seed moisture content is known to effect seedling emergence (Pollock, Roos and Manalo, 1969; Roos and Manalo, 1976) and colored and white seed coats differ in their water absorption properties (Wyatt, 1977) seeds were adjusted to 12 $\pm$ 0.5% moisture content prior to planting. Shortly before planting, seeds were treated with Hopkins Bean Seed Protectant, a commercial seed treatment consisting of Captan, Diazinon and Streptomycin Sulfate.

After planting 112.0 Kgs K_2O/ha was applied through Muriate of Potash in furrows along the rows in the sub-plots. This treatment was imposed in view of the known favorable effect of potassium on stand establishment under cold, wet soil conditions (Wang, Attoe and Truog, 1953). Also, since the same plots were to receive additional nitrogen at flowering, it was necessary to achieve a balance between nitrogen and potassium since a higher rate of potassium is known to be essential with increasing levels of nitrogen application. 112.0 KgsNha was applied in the form of Urea in furrows along the rows when the plants were in the early bloom stage.

After planting, plots were kept weed free with manual weeding as required. No irrigation was provided at any stage. Immediately after each planting the soil temperature at 10 cms was observed and recorded. Daily soil temperatures were recorded for each plot until physiological maturity. Data on daily air temperatures and rainfall were obtained from the M.S.U. Experimental Farm Weather Sub Station. Data was taken on the following characters:

1. Seedling emergence (%) - The number of seedling that emerged from the center two rows were counted on the 7th and 14th day from each planting and expressed as the percentage of planted seeds that emerged during that period.
2. Plant stand (%) - The number of plants that were present in a plot 28 days from each planting date. Data was taken from the two center rows and expressed as percentage of planted seeds. This character is heretofore referred to as population density.
3. Preflowering phase - The number of days from planting until at least 5% of the plants in the plot had one open flower.
4. Physiological maturity - Number of days from planting until approximately 90% of the pods and 80% of the leaves in a plot turned yellow.
5. Post flowering phase - Number of days from flowering to physiological maturity.
6. Plant height (cms) - Measured from the soil surface to the tip of the main stem on 10 randomly selected plants from the two center rows. Data was taken at flowering and at physiological maturity.
7. Canopy width (cms) - Horizontal measurement across the row when plants showed their maximum spread. Measurements were taken on plants on which plant height data was taken. Canopy width data was taken at flowering and physiological maturity.
8. Biological yield (Qui/ha) - Total air dried weight of plants manually harvested from a 4 meter length of each of the two center rows in each plot. Measurement included roots, stems, pods and leaves retained by the plants.

9. Seed yield (Qui/ha) - Total weight of clean seeds obtained from plants harvested from a 4 meter length of the two center rows of each plot. After threshing beans were sized using appropriate metal sieves and were stored at room temperature until evaluated.
10. Number of nodes per plant - Average number of nodes counted on 10 randomly harvested plants.
11. Pods/plant - Number of pods on plants harvested from 1 meter length of the center rows divided by number of plants.
12. Seeds per pod - This character was measured on a meter length of the center two rows. Data was obtained from the following formula

$$\text{Seeds/pod} = \frac{\text{Seed Yield}}{\text{100 Seed Weight}} \times \frac{100}{\text{Number of pods}}$$

13. Weight per 100 seeds (gms) - Average weight of two, 100 seed samples of clean seed.
14. Harvest Index (%) - The ratio of economic yield to biological yield and expressed as a percentage.

The plot means for all characters were subjected to analysis of variance. Because of missing values in some parameters such as nodes per plant, pods per plant, seeds per pod and weight per 100 seeds, data analysis was carried out by method of unweighted means (Snedecor and Cochran, 1967) and mean separation was done by using the approximate method (Steel and Torrie, 1960).

RESULTS

SECTION I

SEEDLING EMERGENCE AND POPULATION DENSITY

Planting dates had a significant effect on the rate of seedling emergence and population density of the twelve drybean genotypes tested. Emergence data obtained one week from each planting date (Table 1) revealed that significantly more seedlings emerged in the June 15 planting followed by the May 27th planting. The June 7 planting showed the lowest percentage of seedling emergence of the four dates, but did not differ significantly from May 19 planting. Emergence data obtained 2 weeks after each planting date (Table 2) and stand establishment data (Table 3) obtained four weeks after each date showed that the June 15 planting resulted in significantly higher plant density per plot than the earlier dates, which did not significantly differ from each other.

No significant effect of additional potassium application was detected on seedling emergence and population density.

Significant genotypic differences were noted on rate of seedling emergence and population density per plot. With the exception of the white seeded genotypes Aurora, Viva and P.I. 165426, colored seeded genotypes almost always had significantly higher seedling emergence than the white seeded genotypes one week after each planting date. (Table 1). Viva (Pink) and P.I. 165426 (Black) showed significantly greater seedling emergence at the May 19 planting but did not differ significantly in the subsequent planting dates.

Further observations on seedling emergence made two weeks after each planting date (Table 2) with the goal to examine the competition between early and late emergence showed that the June 7th planting had the highest increase on percentage of seedling emergence after the second

Table 1. EFFECTS OF PLANTING DATES ON EMERGENCE OF DRY BEAN GENOTYPES (% EMERGENCE AT 7th DAY FROM PLANTING).

GENOTYPES	PLANTING DATES				
	MAY 19	MAY 27	JUNE 7	JUNE 15	MEAN
Black Turtle Soup	45.2bc (q)	47.7ab (q)	26.0abcd (p)	64.5ab (r)	45.9bc
Rico-23	39.0abc (pq)	49.4abc (q)	23.5abc (p)	76.2abcd (r)	47.0bcd
Ex-Rico-23	31.2ab (pq)	45.9a (q)	22.1abc (p)	70.4abc (r)	42.4ab
Aurora	33.1ab (p)	56.2abcd (q)	45.7f (pq)	78.6bcd (r)	53.4def
Viva (Pink)	64.2d (q)	68.2d (q)	39.0def (p)	69.2abc (q)	60.2fg
Viva (White)	50.2c (q)	54.7abcd (q)	30.9cde (p)	73.6abcd (r)	52.4cde
Sanilac	32.6ab (pq)	46.4a (q)	27.5abcde (p)	63.8ab (r)	42.6ab
Seafarer	28.5a (pq)	42.5a (q)	13.9a (p)	63.1a (r)	37.0a
Tuscola	33.6ab (p)	49.9abc (q)	30.5bcde (p)	65.6ab (r)	44.9b
Strain No. 20489	31.6ab (pq)	49.9abc (q)	15.9ab (p)	67.0ab (r)	41.1ab
P.I. 165426 (White)	49.6c (pq)	61.6bcd (q)	41.4def (p)	83.1cd (r)	58.9ef
P.I. 165426 (Black)	66.0d (p)	63.4cd (p)	50.7f (p)	86.5d (q)	66.7g
MEAN	42.1pq	52.9qr	30.6p	71.8r	48.9

Means followed by the same letter (a to g) in columns and (p to r) in rows are not significantly different from each other by Duncan's Multiple Range Test at 5% probability level.

week following planting (32.2%) followed by the May 19 (18.4%), May 27 (14.2%) and the June 15 planting (8.8%). Careful examination of the data reveals some interesting findings as to the way some genotypes responded to the planting date treatments. Black Turtle Soup, Rico-23, Ex-Rico-23, Aurora, Seafarer and Tuscola had more than 20% seedlings to emerge two weeks after the May 19 planting while the other genotypes received relatively lower seedlings during the same period. The same genotypes showed a similar performance after two weeks from the May 27 planting. The magnitude of differences between emergence data obtained one week from planting and after two weeks tended to become shortened for each genotype.

Of interest, the June 7 planting had the greatest percentage of seedlings to emerge after two weeks from planting. From 18 to 42.4% additional seedlings emerged after two weeks from this planting date. The differences were greater with large seeded than with small seeded and medium seeded genotypes- Aurora, P.I. 165426 (White) and P.I. 165426 (Black). Although the percentage of additional seedlings emerged after the second week from planting was considerably less with the June 15 planting large seeded genotypes appeared to have received more seedlings than the small or medium seeded genotypes.

Seedling counts were recorded after the fourth week from each planting date to estimate the percent plant stand. While most of the genotypes had some additional seedling emergence two weeks interval after planting when compared to one week, no substantial gain in plant population was observed 14th day from planting. (Table 3)

Comparison of genotypes across all dates revealed that almost all genotypes had the lowest rate of seedling emergence one week after June 7

Table 2. EFFECTS OF PLANTING DATES ON EMERGENCE OF DRY BEAN GENOTYPES (% EMERGENCE AT 14th DAY FROM PLANTING)

GENOTYPES	PLANTING DATES				
	MAY 19	MAY 27	JUNE 7	JUNE 15	MEAN
Black Turtle Soup	69.1	66.7	61.1	79.6	69.2c
Rico-23	62.7	67.7	64.4	82.5	69.9c
Ex-Rico-23	56.9	66.2	61.2	82.5	66.7bc
Aurora	59.2	70.6	67.0	85.0	70.5c
Viva (Pink)	75.9	68.7	76.0	87.0	76.9de
Viva (White)	65.2	70.1	70.5	83.4	72.3cd
Sanilac	47.7	60.6	56.0	70.4	58.7a
Seafarer	51.0	63.0	55.7	68.0	59.4a
Tuscola	54.5	65.6	52.2	75.6	62.0ab
Strain No. 20489	45.0	59.2	55.4	74.9	58.6a
P.I. 165426 (White)	61.7	70.1	59.4	85.0	69.1c
P.I. 165426 (Black)	76.5	76.4	75.1	90.5	79.6e
MEAN	60.5p	67.1p	62.8p	80.6q	67.7

Means followed by the same letter (a to e) in columns and (p and q) in rows are not significantly different from each other by Duncan's Multiple Range Test at 5% probability level.

planting while they showed highest emergence rate one week from June 15 planting. By the end of second week and fourth week from each planting. no genotypes showed different patterns of seedling emergence and plant stand when sown at the three earlier dates while those planted on June 15 always excelled in seedling emergence and plant density per plot.

When the data was averaged over all planting dates and fertility levels and each genotype was considered individually Aurora, Viva (Pink), P.I. 165426 (Black) and P.I. 165426 (White) had significantly greater seedling emergence than other genotypes one week after planting date. Black Turtle Soup and Rico-23 showed significantly lower rate of seedling emergence than those genotypes, but showed higher rate of seedling emergence than the white seeded genotypes. The colored seeded isolines had significantly higher emergence percentage than their white seeded counterparts. Emergence data obtained 2 weeks from each planting date showed that Sanilac, Seafarer, Tuscola and Strain No. 20489 had significnalty lower emergence rate than other genotypes. Also, P.I. 165426 (White) showed significantly lower seedling emergence than its colored seeded counterpart, while Viva (White) did not differ significantly from its pink seeded counterpart. White seeded genotypes Ex-Rico-23, Aurora, Viva and P.I. 165426 showed a relatively higher percentage of seedling emergence after two weeks from planting. The performance of these entries were comparable to Black Turtle Soup and Rico-23.

Data on stand establishment (Table 3) showed that Sanilac, Seafarer, Tuscola and Strain No. 20489 were consistently inferior to the other genotypes. The white seeded entries Aurora, Ex-Rico-23 and Viva and P.I. 165426 showed considerably greater plant stands than the other white

Table 3. EFFECTS OF PLANTING DATES ON PLANT STAND OF DRY BEAN GENOTYPES. (% PLANT STAND AT 4TH WEEK FROM PLANTING).

GENOTYPES	PLANTING DATES				MEAN
	MAY 19	MAY 27	JUNE 7	JUNE 15	
Black Turtle Soup	71.6	74.5	69.3	82.9	74.6bc
Rico-23	66.3	70.7	72.5	82.5	73.0bc
Ex-Rico-23	61.7	67.6	68.7	83.0	70.3b
Aurora	71.2	71.1	72.6	87.0	75.6bc
Viva (Pink)	80.2	79.5	85.0	91.0	83.9d
Viva (White)	65.2	77.9	76.9	89.0	77.3c
Sanilac	47.7	60.6	57.9	77.6	60.9a
Seafarer	51.0	63.0	57.8	73.8	61.4a
Tuscola	54.5	66.7	58.3	76.3	63.9a
Strain No. 20489	45.0	65.1	57.5	77.8	61.4a
P.I. 165426 (White)	63.3	79.0	65.5	89.3	74.3bc
P.I. 165426 (Black)	76.8	81.0	84.9	92.7	83.5d
MEAN	62.9p	71.4p	68.9p	83.6q	71.7

Means followed by the letter (a to d) in columns and (p and q) in rows are not significantly different from each other by Duncan's Multiple Range Test at 5% probability level.

seeded genotypes and were comparable to Black Turtle Soup and Rico-23. However, when the colored seeded isolines were considered as a group, they had significantly higher plant stands than their white seeded counterparts. (Fig. 4A, B, C).

Significant planting date x genotype interaction was noted only for seedling emergence at the 7th day from each planting. This appears to have resulted primarily from the changed ranking of dry bean genotypes planted on June 7th. No significant planting date x fertility levels and genotypes x fertility levels interactions were noted for any parameter concerning population density and seedling emergence.

The second order interaction of planting dates x genotypes x fertility levels was significant only for seedling emergence at the 7th day from planting. It may have resulted from the greater seedling emergence rate shown by some genotypes at the high fertility levels and at certain planting dates. For example, Viva (Pink) at the May 19 planting and Ex-Rico-23, Viva (Pink), Sanilac and Seafarer at the May 27 planting. (Figure 3A, 3B, 3C, 3D, 3E, and 3F).

SECTION II

VEGETATIVE GROWTH AND DEVELOPMENT

Planting dates had a significant affect on all the parameters pertaining the growth and development of the twelve dry bean genotypes included in this study. Plant height and canopy width, at flowering and at physiological maturity, nodes per plant and the preflowering phase tended to decline significantly at the June plantings. No significant effect of additional fertilizer application could be detected for any of these growth and development characters.

Entries planted at the earlier dates were significantly taller both at flowering and at physiological maturity than those planted later. They also had greater canopy width at both stages of interest, had more nodes per plant, and longer preflowering phase at the two earlier plantings than at the two later planting dates.

Significant genotypic differences were observed on the growth and development characters of the 12 dry bean genotypes included in this study. Also, significant planting date x genotype interactions were detected for all the characters.

Regarding plant height, at the June 7th planting the white seeded genotypes had significantly greater plant height than the black seeded genotypes at flowering. However no consistent plant height pattern between black and white seeded genotypes could be observed at the other planting dates (Table 4). Careful inspection of the data did show a trend favoring taller plants of white seeded genotypes at flowering than that of black seeded genotypes. These differences were not as apparent at physiological maturity because black seeded genotypes had significantly greater plant height than the white seeded genotypes.

Table 4. EFFECTS OF PLANTING DATES ON PLANT HEIGHT (IN CMS.) AT FLOWERING OF DRY BEAN GENOTYPES

GENOTYPES	PLANTING DATES				MEANS
	MAY 19	MAY 27	JUNE 7	JUNE 15	
Black Turtle Soup	28.2cde (q)	24.1a (pq)	22.8ab (p)	20.3a (p)	23.8a
Rico-23	23.9abc (pq)	25.9a (q)	19.4a (p)	20.6a (p)	22.4a
Ex-Rico-23	21.0a (p)	25.1a (p)	23.3abc (p)	21.1ab (p)	22.6a
Aurora	30.6de (pq)	33.5cd (q)	27.4bcd (p)	28.0de (p)	29.9c
Viva (Pink)	37.3f (p)	36.1d (q)	30.2de (p)	28.6de (p)	33.0d
Viva (White)	38.1f (q)	33.6cd (pq)	32.8e (pq)	29.8e (p)	33.1d
Sanilac	28.7cde (p)	33.7cd (q)	28.4de (p)	26.9cde (p)	29.4c
Seafarer	28.1cde (q)	27.7ab (q)	27.9cde (q)	22.5abc (p)	26.5b
Tuscola	31.2e (qr)	33.7cd (r)	27.9cde (pq)	24.0abcd (p)	29.2c
Strain No. 20489	27.5cde (pq)	30.7bc (q)	29.8de (pq)	25.7bcde (p)	28.4bc
P.I. 165426 (White)	22.5ab (p)	22.9a (p)	21.4a (p)	19.5a (p)	21.6a
P.I. 165426 (Black)	26.1bcd (q)	25.7a (pq)	21.9a (pq)	21.0ab (p)	23.7a
MEANS	28.4q	29.4q	26.1pq	24.0p	26.9

Means followed by the same letter (a to f) in columns and (p to r) in rows are not significantly different from each other by Duncan's Multiple Range Test at 5% probability level.

Table 5. EFFECTS OF PLANTING DATES ON PLANT HEIGHT (IN CMS) AT PHYSIOLOGICAL MATURITY OF DRY BEAN GENOTYPES.

GENOTYPES	PLANTING DATES MAY 19	 MAY 27	 JUNE 7	 JUNE 15	MEAN
Black Turtle Soup	46.8de (q)	48.3d (q)	41.3de (p)	36.3bc (p)	43.2d
Rico-23	49.2e (r)	43.5bcd (q)	42.5e (q)	35.8bc (p)	42.7d
Ex-Rico-23	38.5bc (p)	39.9b (p)	36.9cd (p)	34.8bc (p)	37.5bc
Aurora	40.1bc (q)	40.8bc (q)	36.6cd (pq)	32.2b (p)	37.4bc
Viva (Pink)	47.9de (r)	45.8cd (qr)	40.9de (pq)	38.8c (p)	42.1d
Viva (White)	46.3de (r)	42.4bc (qr)	39.5de (pq)	37.1bc (p)	41.3d
Sanilac	38.7bc (q)	41.3bc (q)	40.0de (q)	31.9b (p)	37.9bc
Seafarer	35.9b (pq)	39.2b (q)	33.0bc (p)	36.8bc (pq)	36.2b
Tuscola	38.0bc (pq)	42.9bc (q)	38.8de (pq)	36.2bc (p)	38.9c
Strain No. 20489	36.0b (pq)	40.6bc (q)	39.0de (q)	32.4b (p)	37.0bc
P.I. 165426 (White)	29.5a (pq)	32.4a (q)	27.0a (p)	25.4a (p)	28.8a
P.I. 165426 (Black)	30.6a (q)	33.0a (q)	29.0ab (pq)	25.2a (p)	29.4a
MEANS	39.4q	40.8q	37.0pq	33.6p	37.7

Means followed by the same letter (a to e) in columns and (p to r) in rows are not significantly different from each other by Duncan's Multiple Range Test at 5% probability level.

Table 6. EFFECTS OF FERTILITY LEVELS ON PLANT HEIGHT (IN CMS) AT PHYSIOLOGICAL MATURITY OF DRY BEAN GENOTYPES.

GENOTYPES	FERTILITY LEVELS LOW	HIGH	L.S.D. (.05)
Black Turtle Soup	42.1	44.3	n.s.
Rico-23	36.5	48.9	3.5
Ex-Rico-23	32.4	43.1	3.5
Aurora	36.5	38.3	n.s.
Viva (Pink)	38.4	45.5	3.5
Viva (White)	36.9	45.7	3.5
Sanilac	36.4	39.4	n.s.
Seafarer	35.8	36.6	n.s.
Tuscola	37.8	40.0	n.s.
Stain No. 20489	36.5	37.5	n.s.
P.I. 165426 (White)	30.1	27.5	n.s.
P.I. 165426 (Black)	28.9	29.9	n.s.
MEAN	35.8	39.6	

at the two early plantings while the pattern was less clear in the June 7th planting and completely disappeared at the June 15th planting. (Table 5). The two pairs of isolines included in this study were exceptional since no significant difference between their plant height was observed at any planting date.

Ex-Rico-23 and P.I. 165426 (White) did not show significant change in plant height due to variation in sowing date. On the other had, Ex-Rico-23 was the only genotype which did not show significant change in plant height at physiological maturity due to variation in planting date. Although, most genotypes showed significantly decreased plant height at both stages of interest when planted after the May 27th.

When the data was averaged over all dates and fertility levels P.I. 165426 (White) was shortest at both stages of interest while Viva (White) was the tallest at flowering and Black Turtle Soup tallest at physiological maturity. Except for the two pairs of isolines included in this study, white seeded genotypes had significantly greater plant height than black seeded genotypes at flowering but the black seeded genotypes showed significantly greater plant height than the white seeded lines at physiological maturity.

Regarding canopy width, there was a trend towards narrower canopy width with each successive date after May 27 at both stages of interest (Table 7,8). Significant planting dates x genotype interactions were detected both at flowering and physiological maturity. Comparison of genotypes averaged across all dates showed that Ex-Rico-23, Viva (White) and Strain No. 20489 were not significantly different in their canopy width at flowering due to variation in planting dates while Rico-23,

Table 7. EFFECTS OF PLANTING DATES ON CANOPY WIDTH (IN CMS) AT FLOWERING OF DRY BEAN GENOTYPES.

GENOTYPES	PLANTING DATES				MEAN
	MAY 19	MAY 27	JUNE 7	JUNE 15	
Black Turtle Soup	42.9d (q)	40.6bc (q)	38.3bc (pq)	35.8bcd (p)	39.4c
Rico-23	40.0cd (q)	40.1abc (q)	36.8abc (pq)	32.9abc (p)	37.4bc
Ex-Rico-23	37.0bc (p)	40.9bc (p)	38.1bc (p)	38.9d (p)	38.7c
Aurora	39.4bcd (q)	41.9bc (q)	41.1c (q)	34.2abcd (p)	39.1c
Viva (Pink)	41.4cd (q)	41.1bc (q)	40.8c (q)	35.5bcd (p)	39.7c
Viva (White)	39.8cd (p)	40.9bc (p)	39.3c (p)	36.9cd (p)	39.2c
Sanilac	31.6a (p)	38.3abc (q)	34.4ab (pq)	31.1ab (p)	33.8a
Seafarer	38.5bcd (r)	37.3ab (qr)	33.0a (pq)	30.3a (p)	34.8a
Tuscola	37.3bc (pq)	41.2bc (q)	37.0abc (pq)	33.6abc (p)	37.3bc
Strain No. 20489	34.8ab (p)	35.6a (p)	36.6abc (p)	34.2abcd (p)	35.3ab
P.I. 165426 (White)	40.3cd (q)	42.6c (q)	39.4c (pq)	35.1abcd (p)	39.3c
P.I. 165426 (Black)	39.7cd (q)	39.4abc (q)	37.1abc (pq)	33.3abc (p)	37.4bc
MEANS	38.5pq	39.9q	37.6pq	34.3p	37.6

Means followed by the same letter (a to d) in columns and (p to r) in rows are not significantly different from each other by Duncan's Multiple Range Test at 5% probability level.

Table 8. EFFECTS OF PLANTING DATES ON CANOPY WIDTH (IN CMS.) AT PHYSIOLOGICAL MATURITY OF DRY BEAN GENOTYPES.

GENOTYPES	PLANTING DATES				
	MAY 19	MAY 27	JUNE 7	JUNE 15	MEANS
Black Turtle Soup	52.6b (r)	49.9abc (qr)	46.9ab (pq)	43.0abcd (p)	48.1cde
Rico-23	48.4ab (p)	48.5abc (p)	47.1ab (p)	44.1bcd (p)	47.0abcde
Ex-Rico-23	49.3ab (qr)	50.3bc (r)	45.1ab (pq)	44.2bcd (p)	47.2bcde
Aurora	49.3ab (qr)	52.1c (r)	45.3ab (q)	38.7a (p)	46.3abc
Viva (Pink)	48.7ab (q)	48.7abc (q)	44.9ab (pq)	43.6abcd (p)	46.5abcd
Viva (White)	47.9ab (q)	49.3abc (q)	46.4ab (pq)	41.8abc (p)	46.3abc
Sanilac	46.6a (q)	45.2a (q)	48.7b (q)	39.7ab (p)	45.0ab
Seafarer	48.4ab (q)	45.9ab (pq)	42.5a (p)	41.6abc (p)	44.6a
Tuscola	48.2ab (pq)	50.7bc (q)	47.6b (pq)	45.5cd (p)	48.0cde
Strain No. 20489	49.1ab (q)	47.2abc (q)	46.5ab (q)	41.2abc (p)	46.0abc
P.I. 165426 (White)	49.8ab (p)	50.1abc (p)	49.4b (p)	46.8d (p)	49.0e
P.I. 165426 (Black)	49.1ab (p)	50.9bc (p)	48.7b (p)	47.2d (p0	48.9de
MEANS	48.9q	49.1q	46.6pq	43.1p	46.9

Means followed by the same letter (a to e) in columns and (p to r) in rows are not significantly different from each other by Duncan's Multiple Range Test at 5% probability level.

P.I. 165426 (Black) and P.I. 165426 (White) did not show significant difference in canopy width at physiological maturity due to variation in sowing date. No consistent pattern of differences could be observed between the canopy width of black and white seeded genotypes. Also, the two pairs of isolines did not show significant differences in canopy width between their counterparts at both stages of interest due to variation in sowing date.

Data averaged over all planting dates and fertility levels showed Sanilac to have the narrowest and Viva (Pink) the greatest canopy width at flowering while Seafarer had the narrowest and P.I. 165426 (White) had the greatest canopy width at physiological maturity.

Genotypes planted at the two earlier plantings had significantly higher number of nodes per plant, while those planted at June 15 had the least number of nodes per plant. Except for P.I. 165426 (Black) which had significantly higher number of nodes per plant at May 27 planting than the earliest planting and Rico-23 which did not show any significant differences for nodes per plant due to variation in sowing dates, no significant differences were observed on number of nodes per plant of other genotypes between the two early plantings. Viva (Pink) had significantly greater number of nodes per plant than its white seeded counterpart at the two earlier plantings. Most genotypes exhibited significantly lower number of nodes per plant when sown in June. Although no distinct pattern could be observed between colored and white seeded genotypes, Viva (Pink) and P.I. 165426 (Black) along with their white seeded counterparts had significantly greater number of nodes per plant than the other genotypes at each planting date. (Table 9).

Averaged over all planting dates and fertility levels, Ex-Rico-23 had the lowest number of nodes per plant while Viva (Pink) had the highest

Table 9. EFFECTS OF PLANTING DATES ON NUMBER OF NODES PER PLANT OF DRY BEAN GENOTYPES.

GENOTYPES	PLANTING DATES MAY 19	 MAY 27	 JUNE 7	 JUNE 15	MEAN
Black Turtle Soup	17.9a (pq)	20.2ab (q)	15.4ab (p)	14.9a (p)	17.1abc
Rico-23	18.9a (p)	17.9a (p)	20.7c (p)	20.9c (p)	19.6e
Ex-Rico-23	18.2a (q)	18.8ab (q)	12.4a (p)	12.8a (p)	15.6a
Aurora	18.6a (r)	17.4a (qr)	15.6ab (pq)	13.5a (p)	16.2ab
Viva (Pink)	37.9d (q)	38.4d (q)	23.4cd (p)	22.2c (p)	30.5g
Viva (White)	32.5c (q)	34.4c (q)	22.4cd (p)	24.8c (p)	28.5f
Sanilac	25.2b (q)	19.1ab (p)	16.9b (p)	15.6a (p)	19.2de
Seafarer	21.5a (q)	17.3a (p)	15.3ab (p)	14.0a (p)	17.0abc
Tuscola	19.6a (q)	20.6ab (q)	16.7b (pq)	13.5a (p)	17.6bcd
Strain No. 20489	20.6a (q)	21.9b (q)	16.0ab (p)	16.3ab (p)	18.7cde
P.I. 165426 (White)	37.1c (r)	40.0d (r)	25.7d (q)	19.8bc (p)	29.4fg
P.I. 165426 (Black)	34.6cd (q)	39.8d (r)	24.0d (p)	20.6c (p)	29.7fg
MEAN	24.8r	25.5r	18.7q	17.4p	21.6

Means followed by the same letter (a to g) in columns and (p to r) in rows are not significantly different from each other by Duncan's Multiple Range Test at 5% probability level.

white seeded counterpart.

Entries planted on May 19 had the longest period from planting to flowering while the June 15 planting had the shortest period. However, genotypes planted on June 7 took one day longer from planting to bloom than those planted on May 27. (Table 10).

The earliest planting resulted in the longest preflowering phase of each genotype which spent more than 50% of their life cycle in the vegetative phase, which was most pronounced in Black Turtle Soup, Rico-23, Sanilac and Strain No. 20489. The same genotypes spent more than 50% of their life cycle in vegetative phase when sown on May 27 while other genotypes had shorter vegetative phase than reproductive phase. In the 7th June planting, Black Turtle Soup, Rico-23, Viva (Pink), Viva (White), Sanilac, Seafarer, Tuscola and Strain No. 20489 spent more than 50% of their life cycle in vegetative phase while Ex-Rico-23 had shorter vegetative phase and Aurora had exactly 50% of the life cycle in vegetative phase. Except for Seafarer which spent exactly 50% of its life cycle in the vegetative phase, the June 15 planting resulted in all genotypes spending less than half their life cycle in the vegetative phase.

When the data was averaged across planting dates, genotypic comparison revealed the following four patterns, despite the trend towards a reduced preflowering period with delay of planting. Black Turtle Soup was the only genotype which did not show significant difference in the preflowering phase at the two intermediate plantings. Rico-23, Ex-Rico-23, Aurora, Viva (Pink) and Seafarer showed significantly longer preflowering phase at June 7 planting than at the May 27 planting. While Viva (White) and P.I. 165426 (Black) did not significantly differ in their preflowering phase at May 19 and June 7 planting, Sanilac Tuscola,

Table 10. EFFECTS OF PLANTING DATES ON FLOWERING (IN DAYS) OF DRY BEAN GENOTYPES.

GENOTYPES	PLANTING DATES MAY 19	 MAY 27	 JUNE 7	 JUNE 15	 MEAN
Black Turtle Soup	50.0d (r)	47.0f (q)	46.0e (q)	42.0d (p)	46.0e
Rico-23	50.0d (s)	46.0ef (q)	47.0f (r)	43.0d (p)	46.0e
Ex-Rico-23	42.0ab (s)	38.0b (q)	41.0b (r)	35.0a (p)	39.0b
Aurora	42.0ab (s)	39.0b (q)	40.0b (r)	36.0a (p)	39.0b
Viva (Pink)	42.0ab (s)	38.0b (q)	41.0c (r)	36.0a (p)	39.0b
Viva (White)	41.0a (r)	38.0b (q)	41.0c (r)	36.0a (p)	39.0b
Sanilac	47.0c (s)	46.0e (r)	43.0d (q)	38.0c (p)	43.0d
Seafarer	41.0a (s)	37.0a (q)	39.0a (r)	36.0a (p)	38.0a
Tuscola	47.0c (s)	44.0d (r)	43.0d (q)	38.0c (p)	43.0d
Strain No. 20489	46.0c (s)	45.0e (r)	43.0d (q)	38.0c (p)	43.0d
P.I. 165426 (White)	42.0b (s)	39.0c (r)	41.0c (q)	37.0b (p)	40.0c
P.I. 165426 (Black)	42.0ab (r)	39.0c (q)	42.0c (r)	37.0b (p)	40.0c
MEAN	44.0s	41.0q	42.0r	38.0p	

Means followed by the same letter (a to f) in columns and (p to s) in rows are not significantly different from each other by Duncan's Multiple Range Test at 5% probability level.

Strain No. 20489 and P.I. 165426 (White) exhibited significantly reduced preflowering phase with successive delay in planting.

The two black seeded genotypes Black Turtle Soup and Rico-23 showed significantly longer preflowering phase than the rest of genotypes at each planting date. Regarding the two pairs of isolines included in the study, no significant differences between the preflowering phase of the colored and white seeded counterparts could be detected.

When averaged over all planting dates and fertility levels, Black Turtle Soup, Rico-23, Sanilac, Tuscola and Strain No. 20489 showed more than 50% of their life cycle in the vegetative stage, while the other genotypes spent 50% of less of their life cycle growing vegetatively, Seafarer had the shortest period from planting to flowering while Black Turtle Soup and Rico-23 both black seeded genotypes had the longest preflowering phase.

Except for plant height at physiological maturity, no interaction involving fertility levels was significant for any growth and development characters of dry bean genotypes included in this study. Significant genotypes x fertility levels interaction was detected for plant height at physiological maturity. Rico-23, Ex-Rico-23, Viva (Pink) and Viva (White) showed significantly greater plant height with additional fertilizer application (Table 6).

SECTION III

PHYSIOLOGICAL MATURITY AND YIELD

The dates of planting had a significant effect on postflowering period, biological yield, seed yield and harvest index of the dry bean genotypes included in the study.

The May 19 planting resulted in the shortest postflowering period while the May 27 planting showed the longest postflowering period. (Table 11). The two May plantings had significantly higher biological yield than the two later plants. (Table 12). Highest seed yields were obtained from the May 27 planting followed by the May 19 planting and the two June plantings. (Table 13). Harvest Index was highest at the May 27 planting and lowest at the June 7 planting (Table 14).

No significant effect of additional fertilizer application was detected in any of these parameters. Significant genotypic differences were observed. Also, significant planting date x genotype interactions were noted for all the characters.

When the genotypes were compared acorss planting dates, Black Turtle Soup showed significantly longer postflowering period with successive delay in planting while Rico-23 did not significantly differ in postflowering period between the two later planting dates. Except for Sanilac and Strain No. 20489 which exhibited the longest postflowering period at the June 15 planting, all other genotypes had the longest postflowering period at May 27th planting. Although no consistent pattern of differences emerged between the colored and white seeded genotypes, P.I. 165426 (white) showed significantly longer postflowering

Table 11. EFFECTS OF PLANTING DATES ON POSTFLOWERING PERIOD (IN DAYS) OF DRY BEAN GENOTYPES.

GENOTYPES	PLANTING DATES				MEAN
	MAY 19	MAY 27	JUNE 7	JUNE 15	
Black Turtle Soup	34.0ab (p)	39.0a (q)	41.0c (r)	45.0e (s)	40.0c
Rico-23	32.0a (p)	41.0bc (q)	44.0d (r)	45.0e (r)	41.0d
Ex-Rico-23	36.0bcd (p)	47.0d (r)	44.0d (q)	43.0de (q)	42.0e
Aurora	37.0cd (p)	46.0d (r)	40.0bc (q)	41.0bcd (q)	41.0d
Viva (Pink)	37.0cd (p)	45.0d (r)	38.0ab (p)	43.0cde (q)	41.0d
Viva (White)	37.0cd (p)	46.0d (r)	38.0ab (p)	43.0cde (q)	41.0d
Sanilac	35.0bc (p)	39.0a (q)	38.0ab (q)	41.0bcd (r)	38.0b
Seafarer	33.0ab (p)	43.0c (r)	37.0a (q)	36.0a (q)	37.0a
Tuscola	35.0bc (p)	43.0c (r)	41.0c (q)	40.0bc (q)	40.0c
Strain No. 20489	38.0d (p)	40.0ab (q)	39.0abc (pq)	43.0cde (r)	40.0c
P.I. 165426 (White)	35.0ab (p)	45.0d (s)	38.0ab (q)	42.0cd (r)	40.0c
P.I. 165426 (Black)	34.0ab (p)	42.0c (s)	38.0ab (q)	39.0b (r)	38.0b
MEAN	35.0p	43.0r	40.0p	42.0q	40.0

Means followed by the same letter (a to e) in columns and (p to s) in rows are not significantly different from each other by Duncan's Multiple Range Test at 5% probability level.

period than its black seeded counterpart only at the second and the last planting. When the data was averaged over all planting dates and fertility levels, Seafarer showed the shortest postflowering period while Ex-Rico-23 had the longest postflowering period. (Table 11).

Regarding biological yield, (Table 12) comparison of genotypes across all planting dates showed the highest biological yield of each genotype was associated with either of the two May plantings while most genotypes exhibited the lowest biological yield at the last plantings. Black Turtle Soup, Aurora, Sanilac, Seafarer and P.I. 165426 (White) displayed lower biological yield with progressive delay in planting while Rico-23, Viva (Pink), Viva (White), Tuscola, Strain No. 20489 and P.I. 165426 (Black) showed highest biological yield when sown on May 27 followed by the May 19, June 7 and June 15 plantings. Though Ex-Rico-23 showed the same trend, it exhibited a small but nonsignificant increase in biological yield at June 15th planting than at June 7 planting.

No consistent pattern of differences emerged between the black and white seeded genotypes at any planting date except that Viva (Pink) showed significantly higher biological yield at the two early plantings than its white seeded counterpart (Table 12). Averaged over all planting dates and fertility levels Aurora and Sanilac showed the lowest biological yield while Viva (Pink) showed the highest biological yield.

With the exception of Black Turtle Soup, which showed progressive decline in seed yield with each successive dalay in planting, all other genotypes showed highest seed yields at the May 27 planting followed by the earliest planting. (Table 13). Ex-Rico-23, Viva (White) and P.I. 165426 (Black) showed slightly increased but nonsignificant increase in seed yields when sown on June 15 than when sown on June 7 and P.I.

Table 12. EFFECTS OF PLANTING DATES ON BIOLOGICAL YIELD (IN QUNITALS/ HA) OF DRY BEAN GENOTYPES.

GENOTYPES	PLANTING DATES				
	MAY 19	MAY 27	JUNE 7	JUNE 15	MEAN
Black Turtle Soup	83.8abc (q)	73.4abc (q)	55.7ab (p)	44.7ab (p)	64.4ab
Rico-23	70.6a (q)	92.5e (r)	62.4abc (pq)	47.6abc (p)	68.3bc
Ex-Rico-23	73.7ab (q)	80.4bcde (q)	51.6ab (p)	54.9abcd (p)	65.1ab
Aurora	79.0ab (r)	60.9a (q)	49.5a (q)	40.1ab (p)	57.4a
Viva (Pink)	98.6c (r)	112.7f (r)	81.2d (pq)	65.7d (p)	89.6d
Viva (White)	73.9ab (pq)	90.4cde (q)	76.0cd (p)	62.7cd (p)	75.8c
Sanilac	70.2a (q)	68.ab (q)	55.2ab (q)	37.3a (p)	57.9a
Seafarer	86.8abc (r)	69.6ab (q)	46.3a (p)	45.6abc (p)	62.0ab
Tuscola	87.7abc (q)	91.2de (q)	51.4ab (p)	44.4ab (p)	68.7bc
Strain No. 20489	69.9a (qr)	74.5abcd (r)	57.4ab (q)	47.9abc (p)	62.4ab
P.I. 165426 (White)	89.8bc (q)	85.9bcde (q)	67.8bcd (pq)	57.1bcd (p)	75.2c
P.I. 165426 (Black)	80.8ab (qr)	89.3cde (r)	67.8bcd (pq)	57.6bcd (p)	73.9c
MEAN	80.4q	82.5q	60.2p	50.5p	70.9

Means followed by the same letter (a to f) in columns and (p to r) in rows are not significantly different from each other by Duncan's Multiple Range Test at 5% probability level.

Table 13. EFFECTS OF PLANTING DATES ON SEED YIELD (IN QUINTALS/HA) OF DRY BEAN GENOTYPES.

GENOTYPES	PLANTING DATES				MEAN
	MAY 19	MAY 27	JUNE 7	JUNE 15	
Black Turtle Soup	29.9cd (q)	27.3ab (q)	16.7b (p)	16.6bcd (p)	22.6b
Rico-23	25.9abcd (q)	32.9bcd (r)	20.0bc (p)	18.9cde (p)	24.5bc
Ex-Rico-23	29.2bcd (q)	35.2cd (r)	19.9bc (p)	23.2ef (p)	26.9cd
Aurora	23.9ab (q)	26.9a (q)	8.3a (p)	7.4a (p)	16.6a
Viva (pink)	35.5e (p)	36.1d (p)	32.3e (p)	31.9h (p)	33.9e
Viva (White)	31.2de (pq)	35.4cd (q)	29.2de (p)	30.2gh (p)	31.5e
Sanilac	27.2abcd (qr)	29.5abc (r)	23.4c (q)	14.9bcd (p)	23.7b
Seafarer	23.0a (q)	32.6abcd (r)	21.4bc (q)	13.8bc (p)	22.7b
Tuscola	29.3bcd (q)	31.7abcd (q)	15.6b (p)	11.3ab (p)	21.9b
Strain No. 20489	24.5abc (q)	31.2abcd (r)	19.9bc (pq)	17.9cde (p)	23.4b
P.I. 165426 (White)	24.9abc (q)	32.7abcd (r)	20.0bc (p)	20.0de (p)	24.4bc
P.I. 165426 (Black)	24.3abc (p)	35.1cd (q)	25.3cd (p)	25.7fg (p)	27.6d
MEAN	27.4q	32.2r	21.0p	19.3p	24.9

Means followed by the same letter (a to h) in columns and (p to r) in rows are not significantly different from each other by Duncan's Multiple Range Test at 5% probability level.

165426 (White) was stable. The other genotypes showed progressive decline in seed yields with delay in planting after May 27. (Figures 5A, B, C).

Though no consistent pattern of differences emerged between the seed yields of colored and white seeded genotypes at any planting date, P.I. 165426 (Black) showed significantly higher seed yields than its white seeded counterpart at the June 15 planting. Viva (Pink) was the only genotype which did not show significant difference in seed yields across planting dates. Aurora showed dramatic decrease in seed yields when planted in June.

When the data was averaged over all planting dates and fertility levels, Aurora was the lowest yielding genotype while Viva (Pink) was the highest yielder. When considered as a group, colored seeded genotypes showed higher seed yields than white seeded genotypes, though they were statistically nonsignificantly higher seed yields than its white seeded counterpart.

Harvest indices (Table 14) were determined to examine the efficiency of partitioning of photosynthate between vegetative and reproductive organs of dry bean genotypes when sown at different dates. Rico-23, Ex-Rico-23, Sanilac and Strain No. 20489 did not reveal significant change in harvest indices due to variation in sowing date suggesting that decline in seed yields of these genotypes paralleled with decline in biological yield. The highest harvest indices of most genotypes Ex-Rico-23, Aurora, Sanilac, Seafarer, Strain No. 20489 and P.I. 165426 (White) were associated with the May 27 planting while Viva (Pink), Viva (White) and P.I. 165426 (Black) showed maximum harvest index at

Table 14. EFFECTS OF PLANTING DATES ON HARVEST INDEX (%) OF DRY BEAN GENOTYPES.

GENOTYPES	PLANTING DATES				MEAN
	MAY 19	MAY 27	JUNE 7	JUNE 15	
Black Turtle Soup	37.5cd (q)	36.7ab (q)	30.4bcd (p)	38.8cd (q)	35.8cd
Rico-23	37.6cd (p)	37.2ab (p)	33.5bcde (p)	39.7cde (p)	36.9cde
Ex-Rico-23	41.3d (p)	44.6bc (p)	38.8defg (p)	41.7def (p)	41.6fg
Aurora	31.7abc (q)	43.6abc (r)	17.5a (p)	18.6a (p)	27.8a
Viva (Pink)	38.8cd (p)	36.0ab (p)	40.3efg (p)	48.9f (q)	41.0efg
Viva (White)	43.0d (pq)	41.9abc (pq)	38.8defg (p)	48.3ef (q)	43.0g
Sanilac	40.9d (p)	42.6abc (p)	42.5fg (p)	39.8cde (p)	41.5fg
Seafarer	27.5a (p)	47.1c (q)	45.8g (q)	31.2bc (p)	37.9cdef
Tuscola	35.5abcd (q)	35.3a (q)	27.5b (p)	24.2ab (p)	30.6ab
Strain No. 20489	36.3bcd (p)	41.5abc (p)	35.2bcdef (p)	38.4cd (p)	37.8cdef
P.I. 165426 (White)	28.4ab (p)	39.7abc (q)	29.6bc (p)	36.5cd (q)	33.6bc
P.I. 165426 (Black)	30.8abc (p)	40.8abc (q)	38.ocdefg (q)	44.3def (q)	38.5def
MEAN	35.8	40.6	34.8	37.5	

Means followed by the same letter (a to q) in columns and (p to r) in rows are not significantly different from each other by Duncan's Multiple Range Test at 5% probability level.

the June 15 planting. Tuscola was the only genotype with highest harvest index at the earliest planting while Viva (Pink) was the only genotype with lowest harvest index at the May 27 planting.

The lowest harvest indices of Black Turtle Soup, Rico-23, Ex-Rico-23, Aurora, Viva (White), Strain No. 20489 and P.I. 165426 (White) were associated with the June 7 planting. Sanilac and Tuscola exhibited lowest harvest index at the last planting while that of Seafarer and P.I. 165426 (Black) were associated with the earliest planting.

Figures 6A, B, C show the pattern of change in harvest indices of each genotypes planted at different dates. No consistent pattern of differences emerged between the harvest indices of colored and white seeded genotypes at any date. Also, the two pairs of isolines did not show significant differences in their harvest indices, though colored seeded lines tended to have higher values than their white seeded counterparts in some cases.

Data averaged over all planting dates and fertility levels showed Viva (White) with the highest harvest index and Aurora with the lowest harvest index. P.I. 165426 (Black) showed significantly higher harvest index than its white seeded counterpart.

Neither planting dates x fertility levels nor genotypes x fertility levels interaction were significant. Also, the second order interaction of planting dates x genotypes x fertility levels was nonsignificant for all these characters.

SECTION IV

YIELD COMPONENTS

Planting dates had significant effects on the yield components of the twelve dry bean genotypes tested. There was a pronounced trend toward a decline in number of pods per plant with successive dates of planting. The two earlier plantings had significantly higher number of seeds per pod than the two last planting dates. The May 27th planting resulted in the heaviest seeds while the June 7th planting produced the lightest seeds.

No significant effect of additional fertilizer application could be detected for any of the yield components. Significant genotypic differences were apparent for each yield contributing parameters.

Comparison of genotypes across all planting dates showed that almost all genotypes produced the greatest number of pods per plants at the earliest sowing date and the least number of pods at the last date (Table 15). For each entry, the number of seeds per pod were greatest at either of the two May plantings and the least per either of the two June sowing dates. (Table 17).

Almost all genotypes produced the heaviest seeds at the second sowing date and the lightest seeds at either of the two June sowings. (Table 19). Rico-23, Viva (White), Sanilac, P.I. 165426 (White) and P.I. 165426 (Black) did not exhibit significant change in weight per 100 seeds due to variation in sowing dates. When considered as a group the colored seeded lines tended to produce heavier seeds than the white seeded lines. Regarding the two pairs of isolines included in this study, P.I. 165426 (Black) had significantly heavier seeds than its white seeded counterpart at each date while Viva (Pink) produced

Table 15. EFFECTS OF PLANTING DATES ON NUMBER OF PODS PER PLANT OF DRY BEAN GENOTYPES.

GENOTYPES	PLANTING DATES				MEAN
	MAY 19	MAY 27	JUNE 7	JUNE 15	
Black Turtle Soup	14.1	13.7	12.3	11.4	12.9a
Rico-23	14.8	13.9	13.6	12.2	13.6a
Ex-Rico-23	20.3	20.5	13.2	14.6	17.1c
Aurora	16.4	16.4	12.9	11.7	14.4ab
Viva (Pink)	16.8	16.1	14.3	13.8	15.3b
Viva (White)	16.9	16.9	14.8	15.2	15.9bc
Sanilac	28.2	21.4	22.1	14.8	21.6e
Seafarer	23.4	20.3	17.2	14.8	18.9d
Tuscola	29.9	24.7	18.8	15.3	22.2e
Strain No 20489	22.7	22.6	19.7	11.2	19.0d
P.I. 165426 (White)	29.1	29.1	29.4	25.5	28.3g
P.I. 165426 (Black)	28.1	25.2	25.1	22.7	25.3f
MEAN	21.7s	20.1r	17.8q	15.3p	18.7

Means followed by the same letter (a to g) in columns and (p to s) in rows are not significantly different from each other by Duncan's Multiple Range Test at 5% probability level.

Table 16. EFFECTS OF FERTILITY LEVELS ON NUMBER OF PODS/PLANTS OF DRY BEAN GENOTYPES

	FERTILITY LEVELS		
GENOTYPES	LOW	HIGH	L.S.D.(.05)
Black Turtle Soup	12.0	13.8	n.s.
Rico-23	11.4	15.8	3.4
Ex-Rico-23	15.0	19.2	3.3
Aurora	14.9	13.9	n.s.
Viva (Pink)	15.5	15.1	n.s.
Viva (White)	15.2	16.6	n.s.
Sanilac	20.6	21.6	n.s.
Seafarer	18.4	19.4	n.s.
Tuscola	22.3	22.1	n.s.
Strain No. 20489	18.2	19.8	n.s.
P.I. 165426 (White)	27.6	29.0	n.s.
P.I. 165426 (Black)	25.1	25.5	n.s.
MEAN	18.0	19.4	

significantly heavier seeds than its white seeded counterpart only at the May 27 and June 15 plantings.

Data averaged over all planting dates and fertility levels showed that the white seeded genotypes had the greatest number of pods per plant than the black seeded genotypes. Although Viva (Pink) did not significantly differ from its white seeded counterpart, P.I. 165426 (Black) showed significantly less pods per plants than its white seeded counterpart. Regarding seeds per pod, when considered as a group, black seeded genotypes had significantly greater number of seeds per pod than the white seeded genotypes, with the exception of Ex-Rico-23. Though, Viva (Pink) did not differ significantly from its white seeded counterpart, P.I. 165426 (Black) had significantly greater number of seeds per pod than its white seeded counterpart. Also, black seeded genotypes tended to produce heavier seeds than the white seeded genotypes with the exception of Ex-Rico-23. The colored seeded lines produced signficantly heavier seeds than their white seeded counterparts.

Significant planting date x genotypes interaction was detected only for weight per 100 seeds. Though Viva produced the heaviest seeds at each date, P.I. 165426 (White) produced the lightest seeds at the two early planting while Aurora produced the lightest seeds at the two later planting dates.

A significant genotypes x fertility levels interaction was observed for pods per plant and seeds per pod. Rico-23 and Ex-Rico-23 had a significantly greater number of pods per plant when grown under the high fertility level than when grown under the low fertility level (Table 16). Except for Sanilac, Seafarer and Tuscola, all other genotypes showed significantly greater number of seeds per pod with additional fertilizer application. (Table 18).

Table 17. EFFECTS OF PLANTING DATES ON NUMBER OF SEEDS PER POD OF DRY BEAN GENOTYPES.

GENOTYPES	PLANTING DATES				MEAN
	MAY 19	MAY 27	JUNE 7	JUNE 15	
Black Turtle Soup	5.0	4.6	3.7	4.3	4.4f
Rico-23	5.1	4.8	4.1	3.6	4.4f
Ex-Rico-23	5.2	5.1	3.8	3.9	4.5f
Aurora	4.6	4.4	2.9	3.1	3.7c
Viva (Pink)	4.4	4.2	3.9	3.7	4.0d
Viva (White)	4.1	4.7	3.7	3.7	4.0d
Sanilac	4.1	3.8	2.9	2.9	3.4b
Seafarer	3.6	3.9	3.7	2.6	3.5b
Tuscola	3.8	3.9	2.7	2.6	3.2a
Strain No. 20489	3.6	3.4	3.4	3.4	3.4b
P.I. 165426 (White)	3.8	4.4	3.5	3.4	3.8c
P.I. 165426 (Black)	4.6	4.4	3.8	4.0	4.2e
MEAN	4.3q	4.3q	3.5p	3.4p	3.9

Means followed by the same letter (a to f) in columns and (p to q) in rows are not significantly different from each other by Duncan's Multiple Range Test at 5% probability level.

Table 18. EFFECTS OF FERTILITY LEVELS ON NUMBER OF SEEDS/POD OF DRY BEAN GENOTYPES.

	FERTILITY LEVELS		
GENOTYPES	LOW	HIGH	L.S.D.(.05)
Black Turtle Soup	4.1	4.7	0.29
Rico-23	4.2	4.5	0.29
Ex-Rico-23	4.1	4.4	0.29
Aurora	3.5	3.9	0.30
Viva (Pink)	3.9	4.2	0.29
Viva (White)	3.7	4.3	0.27
Sanilac	3.4	3.5	n.s.
Seafarer	3.4	3.5	n.s.
Tuscola	3.2	3.3	n.s.
Strain No. 20489	3.3	3.6	0.29
P.I. 165426 (White)	3.5	3.9	0.29
P.I. 165426 (Black)	4.0	4.4	0.28
MEANS	3.7	4.0	

Table 19. EFFECTS OF PLANTING DATES ON WEIGHT PER 100 SEEDS OF DRY BEAN GENOTYPES (WEIGHT PER 100 SEEDS IN GRAMS).

GENOTYPES	PLANTING DATES				MEAN
	MAY 19	MAY 27	JUNE 7	JUNE 15	
Black Turtle Soup	18.9ef (p)	20.0e (q)	18.3de (p)	19.3g (q)	19.1ef
Rico-23	18.9ef (p)	18.7d (p)	18.8e (p)	18.7g (p)	18.8de
Ex-Rico-23	19.8f (q)	21.2f (r)	17.7d (p)	18.6fg (p)	19.3f
Aurora	14.5b (q)	14.6b (q)	12.2a (p)	11.8a (p)	13.3a
Viva (Pink)	24.5g (p)	26.9h (r)	24.1f (p)	25.9i (q)	25.4h
Viva (White)	24.4g (p)	24.6g (p)	25.1f (p)	24.7h (p)	24.7g
Sanilac	16.8c (p)	17.7c (p)	17.7d (p)	17.6ef (p)	17.5c
Seafarer	18.2de (q)	20.4ef (r)	18.3de (q)	16.8de (p)	18.5d
Tuscola	18.4de (q)	18.8d (q)	16.3c (p)	15.9cd (p)	17.4c
Strain No. 20489	17.6cd (pq)	18.4cd (q)	17.2cd (p)	18.4fg (q)	17.9c
P.I. 165426 (White)	12.2a (p)	13.2a (p)	13.1a (p)	13.2b (p)	12.9a
P.I. 165426 (Black)	14.1b (p)	14.7b (p)	14.1b (p)	14.9c (p)	14.4b
MEAN	18.2q	19.1r	17.7p	18.0q	18.3

Means followed by the same letter (a to i) in columns and (p to r) in rows are not significantly different from each other by Duncan's Multiple Range Test at 5% probability level.

No significant planting date x fertility levels interaction was noted, nor was the second order interaction involving planting dates x genotypes x fertility levels significant for any of the yield contributing parameters.

DISCUSSION

The results show that planting date had significant effect on seedling emergence and plant stand of dry bean genotypes included in this study. This may be explained by the soil temperature and moisture conditions that prevailed at the various planting dates. In addition to the soil compaction probably resulting from hand planting this date under wet soil condition, the June 7th planting experienced the lowest soil temperatures (19°C at 10 cms. depth) at the time of planting. The cool soil temperature was reflecting in the comparatively slower emergence of seedlings of all genotypes during the first week after planting. The finding that final plant establishment did not significantly differ from that of the earlier planting dates was probably due to the increase in emergence after the second week from planting due to a substantial increase in soil temperatures and more favorable conditions of soil tilth.

Soil conditions prevailing at the first two planting dates appeared to have had a significant effect in reducing seedling emergence of the cultivars. The May 19 planting (which has 21°C soil temperature at 10 cms. depth at the time of planting and which was followed by a consistently lower temperatures after planting than other planting dates) favored the emergence of colored lines over the white seeded lines after the first week from planting. The consistently higher rate of seedling emergence and plant establishment associated with the June 15th planting (which had 23°C at 10 cms. depth at planting followed by similar temperature after planting) suggest that a more favorable soil environment for seedling emergence and plant establishment might prevail in Michigan when planting is delayed after June 10. This is further corroborated by the May 27 planting which had the highest soil temperature at the time of planting (26°C at 10 cms. depth) but which dropped significantly after planting. Hence, while the initial soil temperature was high, this temperature must be maintained to have a positive influence on seedling emergence and plant establishment.

Works by Harrington (1963), Stakonov (1976) Scarisbrick & Wilkes (1973, 1976) reveal the deleterious effects of low soil temperature conditions on the seedling emergence and final plant stand of dry bean genotypes.

Significant genetic variability were noted for seedling emergence and plant stand. Seed coat color, seed size and initial seed moisture content are known to have profound influence on seedling emergence of dry bean genotypes. In the earliest planting date black seeded genotypes, in general, had higher seedling emergence than the white seeded genotypes first week after planting. Also, the colored seeded genotypes had significantly higher seedling than their white seeded counterparts. Though no consistent pattern of difference in seedling emergence rate arising from seed coat color was detected at the June 15 planting, color seeded lines tended to show greater seedling emergence than white seeded lines. Sanilac, Seafarer, Tuscola and Strain No. 20489 were inferior to the other genotypes in terms of final plant stand, and colored seeded lines showed significantly greater plant stand than their white seeded counterparts.

The relatively higher seedling emergence of small seeded genotypes as compared to large or medium seeded genotypes at the June 7th planting may have been due to soil compaction thatoccurred during planting on this date; a recent rainfall necessitated hand instead of machine planting. Mechanical impedance of bean seedlings to emergence under wet soil conditions has been reported by Orphanas (1977). Furthermore, the relatively lower number of additional seedlings of smaller seeded genotypes than the larger seeded genotypes to emerge during the second week period from this planting is in general agreement with the findings of Hardwick (1972) and Villieris, Nel & Hammes (1974). They have reported that better emergence is obtained by smaller seeded dry bean genotypes under adverse soil conditions most likely because of a lower mechanical resistence encountered during emergence.

Deakin (1974), Dickson (1971) and Wyatt (1977) have reported better emergence of colored seeded lines than white seeded lines of *Phaseolus vulgaris*. Black seeded genotypes are known to adapt much better to adverse environmental conditions than white seeded cultivars and consistently possess an advantage over white when planted in cold, wet or warm soil. Black seeds have greater seed coat dry weight and thickness than white seeds, and these traits are negatively correlated with permeability and rate of osmosis. Osmosis through black seed coats may be slowed by a physical barrier of greater cell numbers, by differences in cell density or by some chemical reaction (i.e. phenolic oxidation) unique to colored seeds. Slower water absorption by colored seeds may permit more uniform swelling of the cotyledons, thereby reducing seed coat and/or cotyledon cracking which are important to germination and early seedling growth. Differences in field emergence of two isogenic lines differing only in seed coat color support the importance of seed coat color.

Significant planting date x genotype intereactions obtained for seedling emergence at 7th day from planting could have resulted from the way genotypes with varying seed coat color and seed size responded to planting date treatments at the initial stage of seedling emergence. Low initial seed moisture content is known to increase chilling stress during imbibition period (Pollock, Roos & Manalo, 1969; Roos & Manalo, 1976) thus leading to increased number of decaying seedlings. However, this variability was controlled by adjusting seed moisture content to 12% prior to planting.

The decline in all growth and yield determining parameters of the genotypes sown in June as compared to those sown in May could be associated with weather conditions prevailing during the vegetative and reproductive stage of genotypes sown from each date. An examination of the soil and air temperatures (Figure 1 and 2) shows lower atmospheric and soil temperatures for the two early planting dates that appeared to favor vegetative growth. The relatively warm day/night temperatures and higher soil temperatures prevailing during the growth cycle of plants sown on the two June plantings appeared to have suppressed vegetative growth. Moreover, since no significant amount of rainfall (Figure 1) occurred from mid-July to the end of August and no irrigation was applied, soil moisture could have been limiting. Though no significant amount of rainfall was received during the vegetative growth of the two earlier plantings, the residual soil moisture was adequate to support optimum vegetative growth of the plants started from the two earlier plantings. Also, since the plants tended to form a closed canopy by the time most of the genotypes entered the reproductive stage of development the loss of soil moisture through evapotranspiration could have been minimized to a considerable extent, which could have contributed to further vegetative growth and node differentiation. Conversely, the crop from the two later plantings could have suffered from inadquate soil moisture from the early development stages because of continued exposure of the bare soil for a longer period when atmospheric temperatures were rising. Also, since the plants could not make adequate vegetative growth to cover the interrow spacing, which was especially true with the plants started from the June 15th planting, evaporative losses of soil moisture could have been responsible for stunted vegetative growth of the plants. Higher soil temperature and moisture stress conditions could have led to earlier nodule senescence, poorly developed root system and the plants would have failed to utilize applied nitrogen because of dry soil conditions.

Also since the plants started from the two early plantings tended to have better root systems than those from the June plantings, the entries started from May planting would have been better able to exploit available soil moisture and nutrients which would have conferred further advantage to the May planted crop.

In addition to exerting inhibitory effect on vegetative growth of plants in the June seedlings the weather pattern appears to have had a marked effect on reproductive development of the late planted crop. Plants sown at the two early plantings experienced relatively lower day/night temperatures at the time of flowering and immediately after flowering while those planted on the two later dates experienced the highest day/night temperatures of the season during flowering followed by fluctuating but high temperatures during their reproductive development. These conditions were of course shared by plants sown at the earlier dates. Nevertheless, soil temperatures were continually rising when the plants from the two later plantings entered reproductive stage of their life cycle. These high temperature conditions coupled with negligible amount of rainfall at the critical period of flowering and podsetting of the plants started from the two later plantings could have led to considerable moisture stress in the plants which would have been accentuated with the progress of season. All these conditions could have led to considerable abortion of the reproductive organs of the plants started from the two later plantings while the relatively lower soil and atmospheric temperatures experienced by plants started from the two earlier plantings during the initial stages of their reproductive development coupled with their ability to make adequate vegetative growth to form closed canopy to cover interrow spacing because of the more favorable environmental conditions during earlier stages of their development could have protected them from extreme moisture stress during the critical stage of pod setting.

Also, since the plants from the two later plantings entered reproductive stage of their life cycle, before they had sufficient vegetative growth limited capacity of photosynthetic system and competition for assimilates between vegetative and reproductive organs could have hampered the influx of photosynthetic products inside the pods resulting in abortion of some ovules in each pod of the plants started from the June plantings. The high temperature conditions coupled with soil moisture deficit could have influenced the individual seed weight through their adverse effect on photosynthate production and assimilate supply to the developing seeds of the late planted crop.

While the relatively smaller differences in biological and seed yield displayed by entries planted on the two early dates could have resulted from a higher plant stand obtained by most genotypes it is difficult to associate population density with the declining biological and seed yield for those genotypes planted on June 7 and 15.

Observations on the data show that although genotypes sown on June 7th had a higher plant population than those sown on May 19th and the highest plant population per unit area was associated with genotypes sown on June 15, most of the June 15th sown entries had the smallest biological yield and seed yield. Data on plant height and canopy width measured at physiological maturity of each genotype show increased vegetative growth of each genotype at the two earlier plantings over the two later plantings.

The decline in seed yield with the two later plantings is accompanied by parallel drop in yield components of each genotype with successive delay in planting. Increasing intensity of environmental stresses experienced by the plants in the two later plantings appears to have greatly influenced pods/plant, seeds/pod and individual seed weight. Increasing trend of atmospheric temperatures and soil temperatures continued depletion of soil moisture resulting from higher evapotranspiratory losses and negligible amount of rainfall leading to moisture stress during critical stages of reproductive development appear to have resulted in considerable yield reduction through their adverse effects on yield components. Increased number of aborted flower, increased rate of ovule abortion because of competition for assimilates among seeds in a pod arising from lowered photosynthetic rate could have exerted a negative influence on each of the yield components in the last two plantings. Also, some genotypes showed ozone injury with delayed planting which could have hampered the photosynthetic activity in leaves.

Physical environments prevailing during the growing season and their subsequent effects on vegetative and reproductive development of dry bean genotypes started from each date showed significant effect on harvest index. The higher harvest indices of many genotypes at the May 27 planting as compared to the earliest planting could have resulted from heavier seeds many genotypes tended to produce at the May 27 planting than at the earlier planting. Moreover, plants from the earlier planting probably had higher moisture content at harvest than those from the later plantings. The lowered harvest indices of many genotypes at the June 7 planting could have resulted from sudden change in environmental conditions by the time they entered reproductive stage of their life cycle. Since they experienced more favorable physical environments during their vegetative development than during their reproductive development, there was considerable decline in seed yields without proportionate decline in biological yields which was ultimately reflected in lowest harvest indices of many genotypes, that succumbed to environmental stresses prevalent during their reproductive development. The relatively higher harvest indices of most of the genotypes at June 15 planting than at May 19 or June 7 planting appears to have resulted from poor vegetative growth of the genotypes sown on June 15 since they encountered increasing intensity of environmental stresses from the very beginning of their life cycle.

The adverse effects of physical environments similar to those associated with the life cycle of the entries sown in June have been widely investigated on several grain legumes. Investigations by Miranda and Belmer (1977), Magalhaes, De'Millar and Choudhary (1978), Dreibrodt (1952), Maurer, Ormord and Scott (1969), Kattan and Fleming (1956), Robins and

Domingo (1956) and Stoker (1974) reveal the deleterious effects of moisture stress during vegetative and reproductive developmental stages of dry bean genotypes. In addition to the retarded growth attributed to moisture stress during vegetative growth, reduced seed yields have been reported because of moisture stress conditions occuring at different stages of crop growth - particularly during flowering stage. Davis (1945) concluded that 57% of blossom set seeds if the maximum temperature did not exceed 24°C. For each degree above 24°C he reported a reduction of approximately 2% in the set of pods. The adverse effects of high air temperatures on seed yields of dry bean has been investigated by Villiers (1975), Villiers, Nel and Hammes (1974), Mack and Singh (1969) and Smith and Prayor (1962) who have found increased number of flower abortion when plants were subjected to high temperature conditions during the blooming period.

Work on soybeans by Jones and Laing (1978), Shaw and Laing (1966), Mann and Jaworski (1970), Saito et al. (1970) Van Schaik and Probst (1958), Summerfield, Bunting and Roberts (1975) have revealed that higher temperatures (30°C) during flowering resulted in increased rate of flower and pod shedding of soybean cultivars. Natochieva (1979), Doss, Pearsen and Roger (1974), Thompson (1978), Buntley, McCutchen and Morgan (1973), Sionit and Kramer (1978), Constable and Heron (1978) have reported decreased soybean yields resulting from moisture stress during flowering and pod filling stage as a result of increased number of aborted flowers, reduced number of seeds per pod and reduced seed weight. Moisture stress in soybean has been reported to lower photosynthetic rate and leaf expansion, to reduce shoot growth to cause early leaf death and hasten maturity (Naylor, Teare and Nickell, 1975; Constable and Heron, 1978; Burch, Smith and Mason, 1978; Sivkumar and Shaw, 1978; and Bunch, 1978).

In cowpeas Summerfield, Wien & Minchin (1976) have reported increased abortion of peduncles, flower and young pods together with accelerated leaf senescence because of high atmospheric temperatures. Roberts et al. (1978) have found that warmer day temperatures not only decrease seeds per pod but also decrease seed weight as a result of decrease in seed growth rate without an increase in seed growth duration.

Works on fababeans by Karamanos (1978) and Elston et al. (1976) reveal inhibitory effect of moisture stress on leaf growth. Ishag (1973), Sprent, Bradford & Norton (1977), El-Nadi (1969, 1970), Keatinge & Shykewich (1977) have reported increased flower-shedding in fababeans resulting from moisture stress during flowering. Jones (1963), Paulsen (1977) and Ishag (1973) have suggested the need for rapid early growth, greater number of nodes produced before flowering, large leaf area duration before flowering and large leaf area at podding nodes for higher yields in fababeans.

Several workers have reported the adverse effects of high air temperatures and moisture stress on pea growth and yields. Bosewell (1926, 1929), Karr, Linck and Swanson (1959), Lamber & Linck (1958), Fletcher et al. (1966), Adedipe and Ormord (1970), Stanfield, Ormord and Fletcher (1966) have investigated the adverse effects of high temperatures and moisture stress on vegetative growth and seed yields. There is a general consensus about the susceptibility of peas to adverse environmental conditions during early reproductive development.

Moisture stress is known to reduce nodule activity in fababeans (Sprent, 1972; Pankhrust & Sprent, 1975). Also, higher soil temperatures are reported to inhibit nodulation in cowpeas. (Philpotts, 1967; Minchin, Huxley & Summerfield, 1976).

The physical environment associated with each planting date showed a significant effect on development of dry bean genotypes. The longest preflowering phase of each genotype associated with the earliest planting could be explained by relatively lower day/night temperatures prevailing during earlier stages of crop development. In response to the shortening day length and increasing trend of air temperatures, genotypes planted on June 15 showed the shortest preflowering phase of each genotype. The June 7 planting showed some interesting results in that despite the shorter day length and higher temperature conditions experienced by the crop started from this date, some genotypes displayed significantly longer preflowering phase than when planted on May 27. This apparent deviation from the trend observed might be explained by the sudden drop in air temperatures prevailing immediately prior to plants sown on June 7 going into the reproductive phase of their life cycle. The sudden drop in air temperature appeared to have significantly delayed the date of first flower of Rico-23, Ex-Rico-23, Viva (Pink), Viva (White), Seafarer, P.I. 165426 (Black) and P.I. 165426 (White). Similar observations have been reported in dry beans by Kemp (1973) who suggested that variability exists for tolerance to low temperatures during initiation and development of flowers. Padda & Munger (1969) suggested that under suboptimal conditions even though flower initiation occurs further development of floral primardia is delayed or completely inhibited.

Works by Enriquez (1975) and Enriquez and Wallace (1974) reveal high correlation between night temperature and days to first flower of dry bean genotypes. Researchers have reported advanced flowering of soybean cultivars when grown under high temperature and shorter day length conditions. (Criswell & Hume, 1972; Lawn & Byth, 1973, 1974; Abel, 1961, Hartwig, 1954; Major et al., 1975; Brown, 1960; Hartwig, 1970; Parker & Borthwick, 1973). Works on cowpeas by Huxley & Summerfield (1974), Summerfield, Wien & Minchin (1976) and on peas by Bosewell (1926) also reveal decreased preflowering phase associated with warmer temperature and shorter day lengths.

Since the coefficient of variability of the data on flower initiation was very low (1.83%) even a single day difference among genotypes in days to first flower was declared significant.

Results showed largest postflowering period of many genotypes sown on May 27 and the shortest when sown on May 19. Figure 1 shows that a negligible amount of rainfall was received during the vegetative and reproductive stage of the genotypes planted on May 19. Higher soil temperatures and air temperatures could have resulted in a higher rate of evapotranspiration which could have, in turn hastened maturity. The phenomena might have curtailed the postflowering period. Despite the fact that the entries planted on May 27 grew under the same environment as the genotypes planted earlier, most genotypes showed the longest postflowering period at this date. Notwithstanding, a more favorable soil environment prevailing during the stage of early plant development associated with May 27 planting could have resulted in the development of better root system. Strong root systems enable the plant to maximize its genetic potential in regards to providing water and nutrients for metabolic events associated with changing patterns of growth and development. Also some rainfall received during the later part of reproductive stage of the crop sown on May 27 could have delayed leaf and pod senescence by enhancing the uptake of water and nutrients.

Correlation studies revealed negative correlations between preflowering and postflowering phase at the two May plantings while they were positively correlated with each other at the two June plantings.

The shorter postflowering period of many genotypes associated with the June plantings than May 27 could have resulted from hastened maturity under delayed sowing conditions. Researchers have reported advanced maturity of soybean cultivars under decreased day length conditions (Hartwig, 1970; Lawn & Byth, 1973; Whigham, 1975, 1976; Leffel, 1951; Abel, 1961). Also water stress is found to hasten maturity by causing early leaf death and cessation of pod filling. (Naylor, Teare & Nickel, 1975; Constable & Heron, 1978; Burch, Smith & Mason, 1978; Karomanos, 1978). These effects would have been further compounded by higher soil and air temperatures experienced by the crop during the course of their development.

The trend towards signficantly taller plants in the two black seeded genotypes - Black Turtle Soup and Rico-23, then the white seeded genotypes at physiological maturity suggests that these black seeded genotypes continued significant vegetative growth during the postflowering period. However, lack of significant plant height differences between the black and white seeded genotypes at physiological maturity when planted on June 15 suggests that environmental stresses were such that the increase of vegetative growth after flowering associated with those two black seeded genotypes was inhibited. Though, these black seeded genotypes had significantly longer preflowering phase than rest of the genotypes at each planting date they tended to be shorter than the white seeded genotypes at flowering indicating slower rate of growth associated with these genotypes as compared to the white seeded gentoypes prior to flowering.

The longest postflowering period exhibited by Sanilac and Strain No. 20489 at June 15 planting suggest that one or more component of the physical environment would have been limiting for ripening of the crop. The increasing trend of postflowering period shown by Black Turtle Soup and Rico-23 could be associated with their capability to continue vegetative growth during the postflowering period. Also, they probably carried pods in different stage of maturity, more likely because of longer flowering period of these genotypes when planted late in the season.

Additional fertilizer application showed significant effect only on certain traits of certain genotypes. It could have resulted from earlier decline in nodule activity of the genotypes that showed positive effects to additional fertilizer application. Earlier senescence of nodules of these genotypes probably activated their roots for greater uptake of soil nitrogen applied at blooming. Moreover, genetic variability for nitrogen uptake and utilization could be another probable reason for this result.

The significant positive effect of additional nitrogen (provided by Urea) at blooming was exhibited by Rico-23, Ex-Rico-23, Viva (Pink) and Viva (White) which showed significantly taller plants at physiological maturity when grown under high fertility levels than at low fertility levels. Only Rico-23 and Ex-Rico-23 showed significantly increased pods per plant with additional fertilizer application. However, significantly increased seeds per pod due to additional fertilizer application were observed in all the genotypes except for Sanilac, Seafarer and Tuscola.

In soybeans, many investigators (Fuehring and Finkner, 1974;

Groneman, 1974; Hera, 1974; Hulpai, 1973; Rios & DosSantos, 1973) have emphasized the importance of combined nitrogen in obtaining maximum yield. They have reported that grain yields are determined by the number of pods and subsequently by the number of seeds retained by the plant which in turn was determined by the levels of nitrogen during the bloom and seed falling period. Favorable effects of nitrogen applied at blooming stage of soybean on pods per plant and seeds per pod have been reported by Mederski et al. (1958), Enken (1959), Shibles & Weber (1966) and Brevedan, Egli & Legget (1978).

Regardless of the possible reason for positive effects of additional fertilization, dry bean genotypes displayed different patterns of response. Since the formation of yield components is considered a sequential event, increased pods per plant of Rico-23 and Ex-Rico-23 at high fertility level suggest the peak demand for nitrogen by these genotypes at a time when the number of pods were being determined. Also, this demand would have continued as long as number of seeds per pod were being determined. The significantly increased plant height shown by these genotypes at the high fertility level indicates the possibility of continued uptake of applied nitrogen by the beginning of pod-setting to near physiological maturity. Since Viva (Pink) and Viva (White) displayed increased seeds per pod and plant height at physiological maturity at high fertility level, their peak demand for Nitrogen could have commenced during seed setting and might have continued through physiological maturity. The other five genotypes that showed only increased seeds per pod due to additional fertilization could be characterized as having lower efficiency of nitrogen utilization since they failed to show increased plant height despite the fact that they appeared to utilize applied nitrogen during seed setting.

However, these assumptions on nitrogen uptake need to be interpreted with great caution in order to arrive at some definite conclusion as to the practical implication of nitrogen fertilizer application during the flowering stage of dry bean genotypes. The L.S.D. (.05) values for pods per plant for Rico-23 and Ex-Rico-23 were 3.4 and 3.3 respectively while those for seeds per pod ranged from 0.27 to 0.30 for different genotypes. The differences between the two fertility levels were just marginal to be declared significant in almost all cases.

Correlation studies (Table 21) showed that plant stand was moderately and positively correlated with seed yields at the May 19th planting while it was negatively correlated with pods per plant suggesting that genotypes with capability to achieve higher stand establishment tended to have less pods per plants. Higher plant density and rapid early growth probably resulted in mutual shading of the leaves with loss of leaf area during pod setting which could have led to considerable flower and pod shedding. However, loss of pods at this planting appears to have been compensated by plant density indicating the desirability of thicker planting under early sowing conditions in order to obtain reasonably high seed yields. Moderate positive correlations of days to physiological maturity and plant height at physiological maturity with seeds per pods and seed weight suggests the desirability of genotypes with long growing period and tall growth habit for early planting conditions. Since seed yield showed moderate positive correlation with seeds/pod and seed weight, breeding genotypes which improve these yield components should be expected to result in high yielding cultivars for early planting conditions.

SUMMARY AND CONCLUSIONS

An experiment was conducted during the summer 1978 at the Crops and Soil Science Farm, MSU, with the objective of investigating the effects of planting dates and Potassium and Nitrogen amendments on the growth, development and yield of dry bean genotypes. The experiment was in a split-split plot design with four replications; four planting dates (May 19, May 27, June 7 and June 15) were the whole plot treatments, two fertility levels (recommended rate of fertilizer applied at plantings vs. recommended rate applied at planting plus additional potassium at planting and nitrogen at flowering) were subplot treatments and twelve dry bean genotypes were sub-subplot treatments. Data were collected on several pertaining to the growth, development and seed yields of each genotype planted at different dates. The following conclusions emerge from this study:

1. Colored seeded genotypes such as Black Turtle Soup, Rico-23, Viva (Pink) and P.I. 165426 (Black) showed higher ratesof emergence during the first week from the May 19th planting than the white seeded genotypes except for Viva (White) and P.I. 165426 (White). Since the plants started from this date experienced the lowest soil temperature regime for couple of days after planting, these genotypes exhibit varying degrees of tolerance to cold, wet soil conditions.

2. Viva (Pink) and P.I. 165426 (Black) had significantly higher seedling emergence than their white seeded counterparts during the first week

period from May 19th planting. Similarly, those colored seeded genotypes had greater percentage of seedling emerged at each planting date than their white seeded counterparts.

3. With the exception of Aurora, Viva (White), Ex-Rico-23 and P.I. 165426 (White) all other white seeded genotypes included in this study showed significantly lower plant stand per unit area regardless of planting dates. Viva (Pink) and P.I. 165426 (Black) were always superior to their white seeded counterparts.

4. The crop started from the June planting probably experienced the adverse environmental conditions for their vegetative growth and reproductive development, which was more intensified with the progress of growing season. This was reflected in terms of decreasing trend of plant height, canopy spread, nodes per plant, biological yield, seed yield and its components with successive delay in planting beyond May 27.

5. Ex-Rico-23 did not show significant change in plant height due to variation in planting dates.

6. Ex-Rico-23, P.I. 165426 (White) and P.I. 165426 (Black) did not show significant change in canopy spread due to variation in planting dates. It could have resulted since these genotypes when planted earlier tended to lodge because of early rapid growth, thus forming more compact canopy than their actual form.

7. The portion of total life cycle spent in vegetative stage tended to decline with each successive delay in planting with concurrent increase in postflowering period.

8. Viva (Pink) appears to be the most stable genotype over the environmental conditions experienced in this study in terms of seed yield while Aurora appears to be the most susceptible genotype. No

significant pattern of differences in seed yield arising from seed coat color could be observed.

9. The decline in seed yield with successive delay in planting parallelled with decline in yield components of which pods per plant was most affected.

10. The lowest seed yield obtained from most genotypes at the June 15 planting despite their having highest plant density at this date suggests that plant population cannot compensate for loss of yield components.

11. Colored seeded lines tend to produce heavier seeds and more seeds per pod but less pods per plant than white seeded lines.

12. The consistently higher seed yield of each genotype started from the two earlier plantings than the two later plantings indicates that advancing dry bean planting to the second half of May could result in substantial gain in seed yields. However, further investigations extended over years at various locations are required to test the stability of genotypes under a wider range of environmental conditions.

13. Though additional application of potassium and nitrogen showed significant positive affect on certain traits of certain genotypes, the affect was not great enough to be of any practical importance.

14. Differential response of dry bean genotypes to additional fertilizer application appears to have some implications for further studies. Further investigations on the response of applied nitrogen by dry beans should include monitoring the nodule and nitrate reductase activity of each genotype grown under different environmental conditions. Such studies would aid in identification of developmental stage with

critical demand for supplemental nitrogen. Also, attempts should be made to assess the relative effectiveness of different forms, sources and methods of applied nitrogen.

BIBLIOGRAPHY

BIBLIOGRAPHY

Abel, G.N. 1961. Response of soybeans to dates of planting in the Imperial Valley of California. Agron. J. 53:95-98.

Abellan, C.E.E., F.L.A. Vives and Z.A. Chacan. 1977. The effect of climate on biomass and seed production of kidney beans. Boletin Technico, Facultad de Agronomia, Universidad de Costa Rico. 10:26.

Abu-Shakra, S. and A. Bassiri. 1972. Effect of inoculation and nitrogen fertilization on nodulation, seed yield and qualities of soybeans. J. Agric. Sci. Comb. 78:179-182.

Adedipe, N.O. and D.P. Ormord. 1970. Air and soil temperature effects on growth of peas to phosphorus fertilizations. J. Amer. Soc. Hort. Sci. 95:111-114.

Allos, H.F. and W.V. Bartholomew. 1959. Replacement of symbiotic fixation of available nitrogen. Soil Sci. 87:61-66.

Appadurao, R. and S.B. Rajakarona. 1967. Leaf contribution to pod yields in kidney bean (*P. vulgaris* L.). Indian J. Agric. Sci. 37:524-525.

Asif, N.G.A. 1970. Effects of N.P.K. fertility levels on yield and nutrient content of beans (*Phaseolus vulgaris* L.) and okra (*Abelmoschus esculentus* (L.) Moench). Ph.D. Dissertation, Kansas State University, Manhattan, Kansas.

Asif, N.G. and J.K. Greig. 1972. Effects of seasonal interaction of nitrogen phosphorus and potassium fertilizers in yield and nutrient content of snap beans (*Phaseolus vulgaris* L.). J. Amer. Soc. Hort. Sci. 97:44-47.

Austin, R.B. and M.S.M. Maclean. 1972b. Some effects of temperature on the rates of photosynthesis and respiration of *Phaseolus vulgaris* L. Photosynthetica 6:41-50.

Beard, B.N. and R.M. Hoover. 1971. Effect of nitrogen on nodulation and yield of irrigated soybeans. Agron. J. 63:815-816.

Bethlemgalvay, G.J. and D.A. Phillips. 1977. Ontogenetic interactions between photosynthesis and symbiotic nitrogen fixation in legumes. Plant Physiol. 60:419-421.

Bezdicek, D.F., R.E. Mulford and B.N. Magee. 1974. Influence of organic nitrogen on soil nitrogen, nodulation, nitrogen fixation and yield of soybeans. Soil Sci. Soc. Amer. Proc. 38:268-273.

Bhangoo M.S. and D.J. Albriton. 1972. Effect of fertilizer nitrogen, phosphorus, and potassium on yield and nutrient content of Lee soybeans. Agron. J. 64:743-746.

Bierhuozen, J.R. and N.M. De Vas. 1959. The effect of soil moisture on the growth and yield of vegetable crops. Report on the Conference on Supplemental Irrigation. Commission VI. Inte. Soc. Soil Sci. Copenhagen. 1958:83-92.

Blomquist, R.V. and C.A. Kust. 1971. Translocation pattern of soybeans as affected by growth substances and maturity. Crop Sci. 11:390-393.

Blonchet, R., N. Gelfi and N. Bosc. 1971. Relationships between water use and yield of various varietal types of soybeans (*Glycine max* (L.) merr). Ann. Agron. 28;261-275.

Boote, K.J., R.N. Gallaher, W.K. Robertson, K. Hinson and L.C. Hammond. 1978. Effect of foliar fertilization on photosynthesis, leaf nutrition and yield of soybeans. Agron. J. 70:787-797.

Borst, N.L. and L.E. Thatcher. 1931. Life story and composition of the soybean plant. Ohio Agric. Exp. Stn. Bull. 494.

Borthwick, H.A. and N.W. Parker. 1939. Photoperiodic responses of several varieties of soybeans. Bot. Gaz. 101:341-365.

Bosewell, V.R. 1926. The influence of temperature upon the growth and yield of garden peas. Proc. Amer. Soc. Hort. Sci. 23:162-168.

Bosewell, V.R. 1929. Factors influencing the yield and quality of peas. Biophysical and biochemical studies. Md. Agric. Exp. Stn. Bull. 306:241-392.

Brevedan, R.E., D.B. Egli and J.E. Leggett. 1978. Influence of N nutrition on flower and pod abortion and yield of soybeans. Agron. J. 10:81-84.

Bromlage, W.J., A. Leopold and D.J. Parrish. 1978. Chilling stress to soybeans during inhibition. Plant Physiol. 61:525-529.

Brown, D.M. 1960. Soybean ecology/development-temperature relationships from controlled-environment studies. Agron. J. 52:493-496.

Brouwer, R. 1964. Cited by J.D.N. Keatinge and C.F. Shaykewich 1977. *In* Effects of the physical environment on the growth and yield of field beans (*Vicia faba minor*) in the Canadian Prairie. J. Agric. Sci. 89:349-353.

Bull, T.A. 1968. Expansion of leaf area per plant in field bean *Vicia faba* L. related to daily maximum temperature. J. Appl. Ecol. 5:61-68.

Bunce, J.A. 1978. Effects of water stress on leaf expansion, net photosynthesis, and vegetative growth of soybeans and cotton. Can. J. Bot. 56:1492-1498.

Buntley, G.J., T. McCutchen and N. Morgan, Jr. 1973. Soybean yields as affected by rainfall distribution during flowering and pod filling. Tenn. Farm Hom. Sci. 88:8-10.

Burris, J.S., O.T. Edge and A.N. Wahab. 1973. Effects of seed size on seedling performance in soybeans II seedling growth and photosynthesis and yield performance. Crop Sci. 13:207-210.

Burris, J.S. and J.N. Knittle. 1975. Partial reversal of temperature-dependent inhibition of soybean hypocatyl elongation by cotyledon excision. Crop Sci. 15:461-462.

Busch, G.L., R.C.G. Smith and W.K. Mason. 1978. Agronomic and physiological response of soybeans and soybean crops to water deficits on crop evaporation, soil water depletion and root distribution. Austral. J. Plant Physiol. 5:169-177.

Castro, R.P.C. and P.A.A. Perera. 1975. The response of beans to N.P.K. fertilization. Thesis Ing. Agr. Montevideo, Uruguay, Universidad de la Republica, Ap. 63.

Chapurina, M.J. 1972. Effect of meterological conditions on the rate of soybean plant development. Field Crop Abst. 1973. 26:206.

Chesney, M.A.D. 1973. Performance of soybean (Glycine max (L.) merr.) in the wet tropics as affected by N.P. and K. Agron. J. 65:887-889.

Chevalier, N. 1978. The response of soybean to potassium fertilizer. In Fertilizer use and production of carbohydrates and lipids. Worblaufen. Bern, Switzerland. Int. Potash Inst. 329-334.

Constable, G.A. and A.B. Heron. 1978. Agronomic and physiological responses of soybean and sorghum crops to water deficits growth, development and yield. Austral. J. Plant Physiol. 5:159-167.

Criswell, J.G. and N.J. Hume. 1972. Variation in sensitivity to photoperiod among early maturing soybean strains. Crop Sci. 12:657-660.

Criswell, J.G., N.J. Hume and J.W. Tanner. 1976. Effect of anhydrous ammonia and organic matter on components of nitrogen fixation and yield of soybeans. Crop Sci. 16:400-404.

Crookston, R.K., J. O'Toole, R. Lee, J.L. Ozbun and D.H. Wallace. 1974. Photosynthetic depression in beans after exposure to cold for one night. Crop Sci. 14:457-467.

Dale, J.E. 1964. Some effects of alternating temperature on the growth of French bean plants. Ann. Bot. 28:127-135.

Dale, J.E. 1965. Leaf growth in Phaseolus vulgaris II temperature effects and the light factor. Ann Bot. 29:293-307.

Dart, P.J., P.A. Huxley, A.R.J. Eaglesham, R.R. Minchin, R.J. Summerfield and J.M. Day. 1977. Nitrogen nutrition of cowpea (Vigna unguiculata) II. Effect of short term applications of inorganic nitrogen on growth and yield of nodulated and non-nodulated plants. Expl. Agric. 13:241-252.

Dart, P.J. and F.V. Mercer. 1965. Cited by R.J. Summerfield et al. 1977. In Nitrogen nutrition of cowpea (Vigna unguniculata) I. Effects of applied nitrogen and symbiotic nitrogen fixation on growth and seed yield. Expl. Agric. 13:129-142.

Dart, P.J. and D.C. Wildon. 1970. Cited by P.J. Dart et al. 1977. In Nitrogen nutrition of cowpea (Vigna unguniculata) II. Effects of short term applications of inorganic nitrogen on growth and yield of nodulated and non-nodulated plants. Expl. Agric. 13:241-252.

Davis, J.P. 1945. The effect of some environmental factors on set of pods and yield of white pea beans. J. Agr. Res. 70:237-247.

Deakin, J.R. 1974. Association of seed color with emergence and seed yield of snap beans. J. Amer. Soc. Hort. Sci. 99:110-114.

Deibert, E.J., M. Bijeriego and R.A. Olson. 1979. Utilization of N fertilizer by nodulations and non-nodulating soybean isolines. Agron. J. 71:717-723.

Delouche, J.C. 1953. Influences of moisture and temperature levels on the germination of corn, soybeans and watermelons. Proc. Assoc. Off. Seed Anal. 43:117-126.

Derman, D.B., D.C. Rupp and L.A. Nooden. 1978. Mineral distribution in relations to fruit development and monocarpic senescence in Anoka soybeans. Amer. J. Bot. 65:205-213.

DeSoza, E.G.A. 1969. Legume nodulation and nitrogen fixation studies in Kenya. East Afri. Agri. Forestry J. 34:295-305.

Dickson, M.N. 1971. Breeding seeds Phaseolus vulgaris L. for improved germination under unfavorable low temperature conditions. Crop Sci. 11:848-850.

Dimitrov. Z. 1972. Characters of growth of root system in the early period of development in some agricultural crops in relation to soil moisture. Raseniev dni Nauki. 9:55-62.

Doss, B.D., E.E. Evans and J.L. Turner. 1977. Irrigation and applied N effects of snapbeans and pickling cucumbers. J. Amer. Soc. Hort. Sci. 102:654-657.

Dreibrodt, L. 1952. Gefassversuch uber den Einfluss der Wasserversorgung anf den Estrang bei Buschbonen. Zeitshcrift Pflanz. 95:353-359.

Eaglesham, A.R.J., F.R. Minchin, R.J. Summerfield, P.J. Dart, P.A. Huxley and J.M. Day. 1977. Nitrogen nutrition of cowpea (Vigna unguniculata) III. Distribution of nitrogen within effectively nodulated plants. Expl. Agric. 13:369-380.

Edwards, R.G. 1934. Relations of germinating soybeans to temperature and length of incubation time. Plant Physiol. 9:1-30.

Edwards, C.J., Jr. and E.E. Hartwig. 1971. Effect of seed size upon rate of germination in soybeans. Agron. J. 63:429-430.

Egli, D.B., J.E. Legget and W.G. Duncan. 1978. Influence of nitrogen stress on leaf senescence and N redistribution in soybeans. Agron. J. 70:43-47.

Eira, R.A. Da. 1974. Fertilization of black beans with phosphorus and potassium and its residual effect. Pesguisa, Agropecuaria Brasileria, Serie Agronomia. 9:121-124.

El-Beltagy, A.S. and N.A. Hall. 1974. Effect of water stress upon endogeneous ethylene levels in Vicia Faba. New Phytolog. 73:47-60.

El-Beltagy, A.S. and N.A. Hall. 1975. Studies on endogeneous levels of ethylene and auxin in Vicia Faba during growth and development. New Phytolog. 75:215-224.

El-Leboudi, A., A. Maksoud and A. Midan. 1976. A note on the interaction between nitrogen and phosphorus for snapbean plants. Egypt J. Soil Sci. 16:21-35.

El-Nadi, A.N. 1969. Water relations of beans. I Effects of water stress on growth and flowering. Expl. Agric. 6:195-207.

El-Nadi, A.N. 1970. Water relations of beans. S. Effects of differential irrigation on yield and seed size of broad beans. Expl. Agric. 6:107-111.

Elston, J.F., A.J. Karamanos, A.N. Kassam and R.M. Wadsworth. 1976. The water relations of the field bean crop. Phil. Trans. R. Soc. Long B. 273:581-591.

Enken, V.B. 1959. Cited by C.S. de Mooy, J. Pesek and E. Spaldon. 1973. In B.E. Caldwell (ed) Soybeans: Improvement, production and uses. Amer. Soc. Agron. Madison, Wis.

Enriguez, G.A. 1975. Effect of temperature and day length on time of flowering in beans (Phaseolus vulgaris L.) Diss. Abst. Int. B 1975. 36:1528-1529.

Enriguez, G.A. and D.N. Wallace. 1974. Effect of temperature and day length on time of flowering in beans (Phaseolus vulgaris L.). Hort. Sci. 9:22.

Evans, L. 1957. The broad bean, in the experimental control of plant growth (ed. F. Went). New York: Chronica Botanica Co. 124-128.

Ezedinma, F.O.C. 1964. Cited by P.J. Dart et al. 1977. In Nitrogen nutrition of cowpea (Vigna unguniculata) II. Effects of short term applications of inorganic nitrogen on growth and yield of nodulated and non-nodulated plants. Expl. Agric. 13:241-252.

Feaster, C.V. 1949. Influence of planting date on yield and other characteristics of soybeans grown in southeast Missouri. Agron. J. 41:57-62.

Fehr, W.R., J.S. Burris and D.R. Gilman. 1973. Influence of seed size and population on yield and other characteristics of soybean (Glycine max (L.) merr.). Agron. J. 65:833-836.

Fisher, J.E. 1963. The effects of short days on fruitset as distinct from flower formation in soybeans. Can. J. Bot. 41:871-873.

Fletcher, H.F., D.P. Ormord, A.R. Mauser and B. Stanfield. 1966. Response of peas to environment. I. Planting date and location. Can. J. Plant Sci. 46:77-85.

Fontes, L.A.N. and A.J. Ohlrogge. 1972. Influence of seed size and population on yield and other characteristics of soybean (Glycine max (L.) merr.). Agron. J. 64:833-836.

Franco, A.A., J.C. Pereira and C.A. Neyra. 1979. Seasonal patterns of nitrate reductase and nitrogenase activities in Phaseolus vulgaris L. Plant Physiol. 63:421-424.

Fuehring, N.D. and R.E. Finkner. 1974. Soybean cultural and varietal trials on the High Plains of eastern New Mexico: Research Report. New Mexico Research Report. New Mex. St. Uni. Agric. Exp. Stn. No. 283:13.

Gableman, W.M. and D.D.F. Williams. 1960. Development studies with irrigated snap beans. Wis. Agric. Exp. Stn. Res. Bull. 221.

Gallo, J.R. and S. Miyasaka. 1961. Chemical composition of the bean plant and nutrient uptake from flowering to maturity. Brazantia 20:867-884.

Garcia, L.R. and J.J. Hanway. 1976. Foliar fertilization of soybeans during the seed filling period. Agron. J. 68:653-657.

Garner, W.W. and H.A. Allard. 1920. Effect of the relative length of day and night and other factors of the environment on growth and reproduction in plants. J. Agric. Res. 18:553-606.

Gilman, D.F., W.R. Fehr and J.S. Burris. 1973. Temperature effects in hypocatyl elongation of soybeans. Crop Sci. 13:246-249.

Grabe, D.R. and R.B. Metzer. 1969. Temperature induced inhibition of soybean hypocatyl elongation and seedling emergence. Crop Sci. 9:331-333.

Graham, P.M. and J.C. Rosas. 1977. Growth and development of indeterminate bush and climbing cultivars of Phaseolus vulgaris L. inoculated with Rhizobium. J. Agric. Sci. 88:503-508.

Graham, P.M. and J.C. Rosas. 1978. Nodule development and nitrogen fixation in cultivars of Phaseolus vulgaris L. as influenced by planting density. J. Agric. Sci. 90:19-29.

Green, D.E., E.L. Pinnel, L.E. Cavanah and L.F. Williams. 1965. Effect of planting date and maturity date on soybean seed quality. Agron. J. 57:165-168.

Groneman, A.F. 1974. Effects of deep placement of nitrogen, phosphorus and potassium fertilizers on dry matter production, nodulation, chemical composition, and yield of soybeans. Field Crop Abst. 1976. 249.

Hague, M.R., R. Prakash and D.P. Shrivastana. 1966. Genotypic and phenotypic correlation studies in soybeans. Proc. Bihar. Acad. Agric. Sci. 15:25-29.

Ham, S.E., J.E. Liener, S.D. Evans, R.D. Frazier and W.W. Nelson. 1975. Yield and composition of soybean seed as affected by N and S fertilization. Agron. J. 67:293-297.

Hammond, L.C., C.A. Black and A.G. Norman. 1951. Nutrient uptake by soybeans on two Iowa soils. Iowa Agric. Exp. Stn. Res. Bull. 384.

Hanway, J.J. and C.R. Weber. 1971a. N, P and K percentages in soybean (Glycine max L.) plant parts. Agron. J. 63:286-290.

Hanway, J.J. and C.R. Weber. 1971b. Accumulation of N, P and K by soybean (Glycine max L.) plants. Agron. J. 63:406-408.

Hanway, J.J. 1975. Interrelated development and biochemical processes in the growth of soybean plants in Lowell: D. Hill (ed) Proc. World Soybean Res. Conf.: University of Illinois, Urbana.

Hardwick, R.C. 1973. Growth and developmental studies - French beans. Ann. Rep. Natl. Veg. Res. Stn. 55-56.

Hardwick, R.C. 1974. Responses of Phaseolus vulgaris to temperature in growth cabinets and the field. Acta Hort. 39:115.

Hardman, L.L. and W.A. Brun. 1971. Effect of atmospheric carbon-dioxide enrichment at different developmental stages on growth and yield components of soybean. Crop Sci. 11:886-888.

Hardwick, R.C. 1972. The emergence and early growth of French and runner beans (P. vulgaris L. and Phaseolus coccineus L.) sown on different dates. J. Hort. Sci. 47:395-410.

Harper, J.E. 1974. Soil and symbiotic nitrogen requirements for optimum soybean production. Crop Sci. 14:255-260.

Harper, J.E. 1971. Seasonal nutrient uptake and accumulation patterns in soybeans. Crop Sci. 14:347-350.

Harper, J.E. and R.L. Cooper. 1971. Nodulation response of soybeans (Glycine max (L.) merr.) to application rate and placement of combined nitrogen. Crop Sci. 11:438-440.

Harper, J.E. and R.H. Hageman. 1972. Canopy and seasonal profiles of nitrate reductase in soybeans (Glycine max (L.) merr.). Plant Physiol. 49:146-154.

Harper, J.E., J.C. Nicholas and R.H. Hageman. 1972. Seasonal and canopy variation in nitrate reductase activity of soybean (Glycine max (L.) merr.) varieties. Crop Sci. 12:382-386.

Harrington, J.R. 1963. The effects of temperature on the germination of several kinds of vegetable seeds. Proc. 16th Int. Hort. Cong. 1962. Vol. II:435-441.

Hartwig, E.E. 1954. Factors affecting time of planting soybeans in the southern states. U.S. Dept. Agric. Circ. 943.

Hartwig, E.E. 1970. Growth and reproductive characteristics of soybeans (Glycine max (L.) merr.) grown under short day conditions. Trop. Sci. 12:47-53.

Hatfield, J.L. and D.B. Egli. 1974. Effect of temperatures on the rate of soybean hypocatyl elongation and field emergence. Crop Sci. 14:423-426.

Hatfield, J.L., D.B. Egli, J.E. Legget and D.E. Peeslee. 1974. Effect of applied N on the nodulation and early growth of soybeans (Glycine max (L.) merr.). Agron. J. 66:112-114.

Hayman, D.S. 1968. The role of cotton and bean seed exudate in pre-emergence infection by Rhizatona solani. Diss. Abstr. 1968. 29, No. 1:10B.

Henderson, J.B. and E.J. Kamprath. 1970. Nutrient and dry matter accumulation by soybeans. North Carolina Agric. Exp. Stn. Tech. Bull. No. 197.

Hera, C. 1964. Response and current practice of grain legume crops in Romania. Field Crop Abst. 1974. 3691.

Hodgson, G.L. 1967. Physiological and econological studies in the analysis of plant environment. XIII. A comparison of the effects of seasonal variations in light energy and temperature on the growth of Helianthus annus and Vicia faba in the vegetative phase. Ann. Bot. 31:291-308.

Hopper, N.W., J.R. Overholt and J.R. Martin. 1979. Effect of cultivar, temperature and seed size on the germination and emergence of soybeans (Glycine max (L.) merr.). Ann. Bot. 44:301-308.

Howell, R.W. 1960. Physiology of the soybean. Adv. Agron. 12:256-310.

Howell, R.W. 1963. Physiology of the soybean. In The soybean (ed. A.G. Norman). Academic Press, New York. 83-88.

Huang, C.Y., J.S. Boyer and L.N. Vanderhoef. 1975a. Acetylene reduction (nitrogen fixation) and metabolic activities of soybeans having various leaf and nodule water potentials. Plant Physiol. 56:222-227.

Huang, C.Y. and J.S. Metcalfe. 1975. Crop Production. Macmillan. 379.

Hulparin. 1973. New developments in techniques of soybean cultivation in irrigated conditions. Field Crop Abst. 1975. 8132.

Humphrey, B.N. 1963. Calcium in the walls of Rhizobium trifolii. Rhizobium Newsletter. 8:116.

Huxley, P.A. and R.J. Summerfield. 1976. Effects of day length and day/night temperatures on growth and seed yield of cowpea. Cu. K 2809 in controlled environments. Ann. App. Biol. 83:259-271.

Huxley, P.A. and R.J. Summerfield. 1974. Effects of night temperature and photoperiod on the reproductive antogency of cultivars of cowpea and of soybean selected for the west tropics. Plant Sci. Lett. 3:11-17.

Huxley, P.A., R.J. Summerfield and A.P. Hughes. 1976. Growth and development of soybean cu. TK5 as affected by tropical day lengths, day/night temperatures and nitrogen nutrition. Ann. Appl. Biol. 82:117-133.

Ishag, H.N. 1973. Physiology of yield in field beans (Vicia faba L.) 80:181-189.

Iwata, N. and A. Utada. 1967. Effect of nitrogen supplied in various stages on the growth and yield of cereal vegetable crops. J. Jpn. Soc. Hort. Sci. 37:57-66.

Izhar, S. and D.N. Wallace. 1967. Effect of night temperature on photosynthesis of P. vulgaris L. Crop Sci. 7:546-547.

Johnson, H.W., H.A. Borthwick and R.C. Leffel. 1960. Effects of photoperiod and time of planting on rates of development of the soybean in various stages of the life cycle. Bot. Gaz. 122:77-95.

Johnson, D.R. and V.D. Leudders. 1974. Effect of planted seed size on emergence and yield of soybeans (Glycine max (L.) merr.). Agron. J. 66:117-118.

Johnson, D.R. and D.J. Major. 1979. Harvest index of soybeans as effected by planting date and maturity rating. Agron. J. 71:538-541.

Johnston, T.J., J.W. Pendleton, D.B. Peters and D.R. Hicks. 1969. Influence of supplemental light on apparent photosynthesis, yield, and yield components of soybeans (Glycine max L.). Crop Sci. 9:577-581.

Jones, L.N. 1963. The effect of soil moisture gradient on growth and development of broad beans (Vicia faba L.). Hort. Res. Edinburgh. 3:13-26.

Jones, P.G. and D.R. Laing. 1978. The effects of phenological and meterological factors on soybean yield. Agric. Neterol. 19:485-495.

Johnson, W.A. and E.E. Evans. 1975. Cited by R.J. Summerfield et al. 1977. In Nitrogen nutrition of cowpea (Vigna unguniculata) I. Effects of applied nitrogen and symbiotic nitrogen fixation on growth and seed yield. Expl. Agric. 13:129-142.

Kambal, A.E. 1969. Components of yield in field beans (Vicia faba L.). J. Agric. Sci. 72:359-363.

Kang, B.T. 1975. Effects of inoculation and nitrogen fertilizer on soybean in western Nigeria. Expl. Agric. 11:23-31.

Karamanos, A.J. 1978. Water stress and leaf growth of field: leaf number and total leaf area. Ann. Bot. 42:1393-1402.

Karr, E.J., A.J. Linck and C.A. Swanson. 1959. The effect of short periods of high temperature during day and night periods on pea yields. Amer. J. Bot. 46:91-93.

Kattan, A.A. and J.W. Fleming. 1956. Effect of irrigation at specific stages of development on yield, quality, growth and composition of snap beans. Proc. Amer. Soc. Hort. Sci. 68:329-293.

Keatinge, J.D. and C.F. Shaykewich. 1977. Effects of the physical environment on the growth and yield of field beans (Vicia faba minor) in the Canadian prairie. J. Agric. Sci. 89:349-353.

Kemp, G.A. 1973. Initiation and development of flowers in beans under suboptimal temperature conditions. Can. J. Plant Sci. 53:623-627.

Kralova, M. and H. Mouchova. 1974. Nutrient uptake by horsebean from ammonium sulfate and potassium nitrate labeled by the 15_N isotope. Restlinna Vyroba. 20:335-343.

Laing, D.R. 1974. Cooperative soybean evaluation program. Univ. Syd. Fac. Agric. Dept. No. 8.

Lakhanov, A.P. 1973. Effect of temperature conditions on yield and chemical composition of seeds in haircat bean. Fixiologiya i Biokhimiya Kul' turnykh Rastenii. 5:303-307.

Lakhanov, A.P. 1975. The role of temperature on the ontogeny of bean plants. Fiziologiya i Biokhimiya Kul' turnykh Rastenii. 22:1001-1006.

Lal, R. 1974. Cited by R.R. Minchin, P.A. Huxley and R.J. Summerfield. 1976. In Effect of root temperature on growth and seed yield in cowpea (Vigna unguniculata). Expl. Agric. 12:279-288.

Lamber, R.G. and A.J. Linck. 1958. Effects of high temperature on yield of peas. Plant Physiol. 33:347-350.

Lambeth, V.N. 1950. Some factors influencing pod set and yield of the lima bean. Res. Bull. No. Agric. Exp. Stn. 466.

Lathwell, D.J. and C.E. Evans. 1951. Nitrogen uptake from solution by soybeans at successive stages of growth. Agron. J. 43:264-270.

Latimore, N., Jr., J. Giddens and D.A. Ashley. 1977. Effect of ammonium and nitrate nitrogen upon photosynthate supply and nitrogen fixation by soybeans. Crop Sci. 17:399-404.

Lawn, R.J. and W.A. Brun. 1973. Symbiotic nitrogen fixation in soybeans. III. Effect of supplemental nitrogen and intervarietal grafting. Agron. J. 65:22-25.

Lawn, R.J. and W.A. Brun. 1974. Symbiotic nitrogen fixation in soybeans. I. Effect of photosynthetic source-sink manipulations. Crop Sci. 14:11-19.

Lawn, R.J. and D.E. Byth. 1973. Response of soybeans to planting date in southeastern Queensland. L. Influence of photoperiod and temperature on phasic developmental patterns. Austral. J. Agric. Res. 24:67-80.

Lawn, R.J. and D.E. Byth. 1974. Response of soybeans to planting date in southeastern Queensland. II. Vegetative and reproductive development. Austral. J. Agric. Res. 25:723-737.

Lawrie, A.C. and C.T. Wheeler. 1974. The effects of flowering and fruit formation on the supply of photosynthetic assimilates to the nodules of *Pisum satireum* in relation to the fixation of nitrogen. New Phytolog. 73Lkkk9-27.

Lauer, D.C. 1979. Foliar fertilization of dry edible beans. Agron. Abst. Annual meeting: ASA, CSSA and SSSA. 175.

Leffel, R.C. 1961. Planting date and varietal effects on agronomic and seed compositional characters in soybeans. Bull. Md. Agric. Exp. Stn. No. A-117.

Lindoo, S.J. and L.D. Nooden. 1976. The interrelationship of fruit development and leaf senescence in 'Anoka' soybeans. Bot. Gaz. 137:218-223.

Listowski, A., I. Jackowskai and A. Wirowski. 1966. Influence of soil humidity and temperature fluctuations on development of horsebean (*Vicia faba* minor) and setting of pods. Pam. Paul. 23:1-21.

Littlejohns, D.A. and J.W. Tanner. 1976. Preliminary studies on the cold tolerance of soybean seedlings. Can. J. Plant Sci. 56:371-375.

Loos, M.A. and N.A. Louw. 1965. The influence of calcium carbonate amendments on the nodulation of white clover in the acid soils. South African J. Agric. Sci. 8:729-736.

Lucas, E.O., G.M. Milbourn and P.N. Whitford. 1976. The translocation of 14_c photosynthate from leaves and pods in *Phaseolus vulgaris*. Ann. Appt. Bio. 82:285-290.

Ludwig, C.A. and F.E. Allison. 1935. Some factors affecting nodule formation on seedlings of leguminous plants. J. Amer. Soc. Agron. 27:895-902.

Lyons, J.C. and E.B. Earley. 1952. The effects of NH_4No_3 application to field soils on nodulation seed yield and nitrogen and oil content of the seed of soybeans. Soil Sci. Soc. Amer. Proc. 16:259-263.

Mack, A.R. 1973. Soil temperature and moisture conditions in relation to the growth and quality of field peas. Can. J. Soil Sci. 53:59-72.

Mack, N.J. and J.B. Singh. 1969. Effects of high temperature on yield and carbohydrate composition of bush snap beans. J. Amer. Soc. Hort. Sci. 94:60-62.

McEwen, J. 1970. Fertilizer, nitrogen and growth regulation for field beans (*Vicia faba L.*). II. The effect of a large dressing of fertilizer nitrogen, single and split applications, and growth regulation. J. Agric. Sci. 74:67-72.

Magalhaes, A.A., A.A. De'Millar and E.N. Choudhary. 1978. Effects of phenological water stress on bean production. Petrolina, Brazil, Centre de Pesquisa Agropecuaria do Tropico Semiarido. 1978. 15.

Major, D.J., D.R. Johnson and V.D. Leudders. 1975. Evaluation of the eleven thermal unit methods for predicting soybean development. Crop Sci. 15:172-174.

Major, D.F., D.R. Johnson, J.W. Tanner and S.C. Anderson. 1975. Effect of day length and temperature on soybean development. Crop Sci. 15:174-197.

Mann, J.D. and E.G. Jaworski. 1970. Comparison of stresses which may limit soybean yield. Crop Sci. 10:620-624.

Maurer, A.R., D.P. Ormord and N.J. Scott. 1969. Effect of five soil water regimes on growth and composition of snap beans. Can. J. Plant Sci. 49:271-278.

Mascarenhas, H. 1966. Influence of various sources of nitrogen and dates of their application in the dry bean culture. Bragantia 25:61-63.

Mederski, N.J., N.N. Wilson, and G.W. Volk. 1958. Response of soybeans to plowdown and sidedress applications of nitrogen on irrigated and non-irrigated soils. Ohio Agric. Exp. Stn. Res. Circ. 59.

Minchin, F.R., P.A. Huxley and R.J. Summerfield. 1976. Effect of root temperature on growth and seed yield of cowpea (*Vigna unguniculata*). Expl. Agric. 12:279-288.

Minchin, F.R., R.J. Summerfield and A.R.J. Eaglesham. 1977. Cited by A.R.J. Eaglesham et al. 1977. *In* Nitrogen nutrition of cowpea (*Vigna unguniculata*) III. Distribution of nitrogen within effectively nodulated plants. Expl. Agric. 13:369-380.

Miranda, N.O. and N.C. Belmer. 1977. Water deficit and frequency of irrigation in bean (*Phaseolus vulgaris* L.). Agric. Tech. 37:111-117.

Montjos, J.C. and A.C. Magalhaes. 1977. Growth analysis of dry beans (_P. vulgaris_ L. var. Pintado) under varying conditions of solar radiation and nitrogen application. Plant and Soil. 35:217-223.

Munson, R.D. 1970. N-K balance - an evaluation. Potassium Review. 16/50:1-23.

Narikawa, T. and T. Muira. 1974. Studies on cool weather tolerance in bean plants. 3. Photosynthetic efficiency of common bean varieties (_P. vulgaris_ L.) under cool temperature conditions. Bull. Hokkaide Prefectural Agric. Exp. Stn. No. 29:55-60.

Natochieva, N.N. 1974. An agrometerological study of sowing dates for soybean. Field Crop Abst. 1975. 28:4578.

Naylor, D.G., I.D. Teare and C.D. Nickell. 1975. Variations in photosynthesis of soybean under nonstressed and stressed conditions. Phyton. 33:103-109.

Norman, A.G. and L.O. Krampitz. 1945. The nitrogen nutrition of soybeans. II. Effect of available soil nitrogen on growth and nitrogen fixation. Soil Sci. Soc. Amer. Proc. 10:191-196.

Nutman, P.S. 1971. Cited by R.J. Summerfield et al. 1977. _In_ Nitrogen nutrition of cowpea (_Vigna unguniculata_) I. Effects of applied nitrogen and symbiotic nitrogen fixation on growth and seed yield. Expl. Agric. 1977. 13:129-142.

Obendrof, R.L. and P.R. Hobbs. 1970. Effect of seed moisture on temperature sensitivity during imbibition of soybean. Crop Sci. 10:563-566.

Odurukwe, S.D. 1973. Differential responses in growth, rate of net photosynthesis, chemical composition and yield of seed among soybean lines from applied NPK fertilizers. Diss. Abst. Int. B. 33:4621.

Ohlraggeo, A.J. 1963. Mineral nutrition of soybeans _In_ The soybean (ed. A.D. Norman). Academic Press. 143-144.

Ohlraggo, A.J. 1966. Mineral nutrition of soybeans. Plant Food Review. Winter 1966.

Ojeda, O.V.A., F.L. Vives and Z.A. Chacan. 1974. Climatic requirements for _P. vulgaris_ in April-July Bulletin Technico Facultad de Agronomico. Universidad de Costa Rica. 7:25-51.

Oliker, N., A. Mayber Polajkoff and A.M. Mayer. 1970. Changes in weight, nitrogen accumulation, respiration and photosynthesis during growth and development of seeds and pods of _Phaseolus vulgaris_. Amer. J. Bot. 65:366-371.

Orcutt, F.S. and P.W. Wilson. 1935. The effect of nitrate nitrogen on the carbohydrate metabolism of inoculated soybeans. Soil Sci. 39:289-296.

Orphanos, P.I. 1977. Emergence of Phaseolus vulgaris seedlings from wet soil. J. Hort. Sci. 52:477-455.

Osler, R.D. and J.L. Carter. 1954. Effect of planting date on chemical composition and growth characteristics of soybeans. Agron. J. 46:267-270.

O'Toole, J.C., J.L. Ozbun and D.M. Wallace. 1977. Photosynthetic response to water stress in Phaseolus vulgaris. Physiol. Plant. 40:111-114.

Padda, D.S. and H.M. Munger. 1969. Photoperiod, temperature and genotype interactions affecting time of flowering in beans, Phaseolus vulgaris L. J. Amer. Soc. Hort. Sci. 52:453-460.

Pal, V.R. and M.C. Saxena. 1975. Responses of soybean to symbiosis and nitrogen fertilization under humid subtropical conditions. Expl. Agric. 11:221-226.

Papanicolau, E.P., V.D. Skarlou and C.G. Apostolakis. 1977. A study of rate and time of application of nitrogen fertilizer labeled with N^{15} in the cultivated beans. Agrochimica. 21:398-407.

Pankhrust, C.E. and J.I. Sprent. 1975. Effects of water stress on the respiratory and nitrogen fixing activity of soybean root nodules. J. Exp. Bot. 26:287-304.

Parker, M.W. and H.A. Borthwick. 1943. Influence of temperature on photoperiodic reactions in leaf blades of Biloxi soybeans. Bot. Gaz. 104:612-619.

Pate, J.S. and P.J. Dart. 1961. Cited by P.J. Dart et al. In Nitrogen nutrition of cowpea (Vigna unguniculata) II. Effects of short term applications of inorganic nitrogen on growth and yield of nodulated and non-nodulated plants. Expl. Agric. 13:241-252.

Peet, M.M., A. Bravo, D.H. Wallace and J.L. Ozbun. 1977. Photosynthesis, stomatal resistance and enzyme activities in relation to yield of field grown varieties. Crop Sci. 17:287-293.

Philpotts, N. 1967. Cited by F.R. Minchin, P.A. Huxley and R.J. Summerfield. 1976. In Effects of root temperature on growth and seed yield in cowpea (Vigna unguniculata). Expl. Agric. 12:279-288.

Pollock, B.M. 1969. Imbibition temperature sensitivity of lima bean seeds controlled by initial seed moisture. Plant Physiol. 44:907-911.

Pollock, B.M., E.E. Rood and J.R. Manalo. 1969. Vigor of garden bean seeds and seedlings influenced by initial seed moisture, substrate oxygen and imbibition temperature. J. Amer. Soc. Hort. Sci. 94:577-584.

Pollock, B.M. and V.K. Toole. 1966. Imbibition period as the critical temperature sensitive stage in germination of lima bean seeds. Plant Physiol. 41:221-229.

Popescu, C. and S. Axinte. 1979. Effect of light and fertilizer on yield and water uptake of soybean. Field Crop Abst. 32:1673.

Posypanov, G.S. 1974. Application of starting rates of nitrogen fertilizers to legumes. Agronkhimiya. 1:17-23.

Poulsen, M.H. 1977. Genetic relationships between seed yield components and earliness in *Vicia faba* L. and the breeding implications. J. Agric. Sci. 89:643-654.

Rachie, K.O. and W.G. Rockwood. 1973. Cited by P.J. Dart et al. 1977. *In* Nitrogen nutrition of cowpea (*Vigna unguniculata*) II. Effects of short term applications of inorganic nitrogen on growth and yield of nodulated and non-nodulated plants. Expl. Agric. 13:241-252.

Rauseo, M.H., F.L.A. Vives and Z.A. Chacon. 1975. Climatic requirements of bean (*P. vulgaris* L.). Baletin Technico Estacion Experimental Agricola, 'Fabio Bandrit N.'. 8:3:22.

Richards, J.E. 1977. The effect of fertilizer nitrogen on yield, crude protein content, and symbiotic fixation in *Vicia faba* L. var. minor. M.S. Thesis. University of Manitoba.

Richards, J.E. and R.J. Soper. 1979. Effect of N fertilizer on yield. Protein content and symbiotic N fixation in fababeans. Agron. J. 71:807-811.

Richardson, D.S., D.C. Jordan and E.N. Garrard. 1957. The influence of combined nitrogen on nodulation and nitrogen fixation by *Rhizobium meliloti*. Can. J. Plant Sci. 37:205-214.

Rinno, G., K. Ebert and N. Wildner. 1973. The effect of nitrogen fertilization on the amino acid content of legumes grown for grain. Tag. Ver. Akad. Landwirtsch Wiss DDRNR. 122:67-75.

Rico, G.P. and H.L. Dos Santos. 1973. Nitrogen fertilization for soybeans on Cerrado soils. Pesquisa Agropecuaria Brasileria Agron. 8:63-67.

Rivero, C.R. and O.C.T. Giraldo. 1976. Nodulation and nitrogen fixation in beans and soybeans. Thesis, Palmira, Universidad Nacional de Columbia. Facultad de ciencias Agropecuarias. 44.

Roberts, E.N. R.J. Summerfield, F.R. Minchin, K.A. Steward and B.J. Ndunguru. 1978. Effects of air temperature on seed growth and maturation in cowpea (Vigna unguniculata). Ann. Appl. Bio. 90:437-446.

Robertson, W.K., K. Hunson and L.C. Hammond. 1977. Foliar fertilization of soybeans (Glycine max (L.) merr.). Fla. Soil and Crop Sci. Soc. Proc. 36:77-79.

Rogalsky, J.R. 1972. Summary of fababean fertility trials. In papers presented at the 16th Ann. Manitoba Soil Sci. Meeting: University of Manitoba, Winnipeg. 169-170.

Roos, E.E. and J.R. Manalo. 1976. Effect of initial seed moisture on snap bean emergence from cold soil. J. Amer. Soc. Hort. Sci. 101:321-324.

Rovira, A.D. 1956. Plant root excretions in relation to the rhizosphere effect. Plant and Soil. 7:178-194.

Runge, R.C.A. and R.T. Odell. 1960. The relationship between precipitation, temperature and yield of soybeans on the Agronomy South Farm, Urbana, Ill. Agron. J. 52:245-247.

Sadler, J.N. 1975. Soil, fertilizer, and symbiotically fixed nitrogen as sources of nitrogen for fababeans under prairie conditions. In papers presented at the 19th Ann. Manitoba Soil Sci. Meeting: University of Manitoba, Winnipeg. 121-128.

Saito, N.T., K.G. Yanamoto and K. Nashimoto. 1970. The influence of cool temperatures before and after anthesis on pod setting and nutrients in soybean plants. Proc. Crop Sci. Soc. 39:511-519.

Scarisbrick, D.N., M.K.V. Carr and J.M. Wilkes. 1976. The effect of sowing date and season on the development and yield of navy beans (P. vulgaris) in southeast England. J. Agric. Sci. 86:65-76.

Scarisbrick, D.N. and J.M. Wilkes. 1973. The effect of drilling date on the seed yield of navy bean (P. vulgaris). Nature. 242:619-620.

Scarisbrick, D.N. and J.M. Wilkes. 1975. Effect of drilling date on the seed yield of the navy bean (P. vulgaris). Hort. Res. 14:117-121.

Schroder, E. 1973. The influence of different growing factors on the yield of French beans. Gartenbau. 20:259-261.

Scroth, M.N., A.R. Weinhold and D.S. Hayman. 1966. The effect of temperature in quantitative differences in exudates from germinating seeds of bean, pea and cotton. Can. J. Bot. 44:1429-1432.

Shaw, R.N. and A.R. Laing. 1966. Cited by W.N. Pierre et al. (eds.) In Plant environment and efficient water use. Amer. Soc. Agron. and Soil Sci. Soc. Amer., Madison, Wis.

Shibles, R.M., I.C. Anderson and A.N. Gibson. 1975. Soybean. In Crop physiology: some case histories. (ed. L.T. Evans) London: Cambridge University Press. 151-190.

Shibles, R.M. and C.R. Weber. 1966. Biological efficiencies in soybean production. Plant Food Rev. Winter. 8-10.

Shupert, J.R. 1971. The effect of seedling vigor, planting depth and planting date on soybean (Glycine max (L.) merr.) production. M.Sc. Thesis. The Ohio State University, Columbus, Ohio.

Sierra, E.M. 1977. Energetic-photo-thermal development model for medium late and late soybean cultivars. Agric. Meterol. 18:277-291.

Simons, J. 1974. Effects of soil temperature and moisture on the germination requirements of fababeans. Unpublished B.Sc. Thesis. Department of Soil Science. University of Manitoba.

Sinclair, T.R. and C.T. DeWit. 1976. Photosynthate and nitrogen requirements for seed production by various crops. Science. 189:565-567.

Sinclair, T.R. and C.T. DeWit. 1976. Analysis of the carbon and nitrogen limitations to soybean yield. Agron. J. 68:319-324.

Singh, C.B., R.K. Misra and S.K. Mehta. 1978. Note on the correlation between some seed characteristics and germination percentage in soybean. Indian J. Agric. Sci. 48:121-122.

Singh, J.N., S.K. Tripathi and P.S. Negi. 1972. Note on the effect of seed size on germination, growth and yield of soybean (Glycine max (L.) merr.). Indian J. Agric. Sci. 42:83-86.

Sinha, S.K. 1973. Yield of grain legumes: problems and prospects. Proc. II SABRAO Congress. Indian J. Genet. 34A:988-994.

Sinha, S.K. 1974. Cited by H.K. Jain 1975. In Breeding for yield and other attributes in grain legumes. Indian J. Genet. 35:169-187.

Sionit, N. and P.J. Kramer. 1977. Effect of water stress during different stage of growth of soybean. Agron. J. 69:274-278.

Sistachs, E. 1970. Effects of nitrogen fertilization and inoculation on yield and nitrogen content of black beans. Revista Cubana de cinecias Agricola. 4:233-237.

Sistachs. E. 1974. Nodulation studies in soybeans, the influence of concentration, farm and time of application of combined nitrogen on symbiotic response. Cuban J. Agric. Sci. 8:203-209.

Siukumar, M.V.K. and R.H. Shaw. 1978. Relative evaluation of water stress indicators for soybeans. Agron. J. 70:619-623.

Smith, Cyril B. 1977. Growth responses, nutrient leaf concentrations and interelement relationships of snap beans as affected by fertilizer treatment. J. Amer. Soc. Hort. Sci. 102:61-84.

Smith, F.L. and R.H. Prayor. 1962. Effects of maximum temperature and age on flowering and seed production in three bean varieties. Hilgardia. 22:669-688.

Smittle, D.A. 1975. Response of snap beans to irrigation and nitrogen fertilization. Hort. Sci. 10:145-146.

Smittle, D.A. 1976. Response of snap bean to irrigation, nitrogen fertilization and plant population. J. Amer. Soc. Hort. Sci. 101:37-40.

Snedecor, G.W. and W.G. Cochran. 1967. Statistical methods. Iowa State Univ. Press. Ames, Iowa.

Sprent, J.I. 1971. Effects of water stress on nitrogen fixation in root nodules. Plant and Soil, Special Volume 1971. 225-228.

Sprent, J.I. 1972. The effect of water stress on nitrogen fixing root nodules. IV. Effects on whole plants of Vicia faba and Glycine max. New Phytol. 71:603-611.

Sprent, J.I. 1976. Nitrogen fixation by legumes subjected to water and light stress. In Symbiotic nitrogen fixation in plants (ed. P.S. Nutman). Cambridge Univ. Press. 405-420.

Sprent, J.I., A.M. Bradford and C. Norton. 1977. Seasonal growth patterns in field bean (Vicia faba L.) as affected by population density, shading and its relationship with soil moisture. J. Agric. Sci. 88:293-301.

Stakonov, F. 1976. Changes in rate and uniformity of germination of Phaseolus vulgaris seeds in relation to temperature. Referativynyizhurnal. 6:445.

Stanfield, B., D.P. Ormord and H.F. Fletcher. 1966. Response of peas to environment II. Effects of temperature in controlled environment cabinets. Can. J. Plant Sci. 46:195-203.

Steel, R.G.D. and J.N. Torrie. 1960. Principles and procedures of statistics. McGraw Hill.

Stewart, W.D.P. 1966. Nitrogen fixation in plants. The Athlone Press: Univ. of London. 14.

Stewart, K.A. and R.J. Summerfield. 1978. Effect of root temperature on floral morphology in cowpea (Vigna unguniculata). Plant and Soil. 49:443-448.

Stocker, R. 1974. Effect on dwarf beans of water stress at different phases of growth. Expl. Agric. 2:13-15.

Streeter, G.L. 1978. Effect of N starvation of soybean plants at various stages of growth on seed yield and N concentration of plant parts at maturity. Agron. J. 70:74-76.

Summerfield, R.J. 1975. Cited by R.J. Summerfield, McWien and F.R. Minchin. 1976. In Integrated field and glass house screening for environmental sensitivity in cowpea (Vigna unguniculata). Expl. Agric. 12:241-248.

Summerfield, R.J., A.N. Bunting and E.H. Roberts. 1975. Use of controlled environment facilities as an adjunct to field research on potentially tropic-adapted grain legumes. Phytotranics Newsl. 11:36-41.

Summerfield, R.J., P.J. Dart, P.A. Huxley, A.R.J. Eaglesham, F.R. Minchin and J.M. Day. 1977. Nitrogen nutrition of cowpea I. Effects of applied nitrogen and symbiotic nitrogen fixation on growth and seed yield. Expl. Agric. 13:129-142.

Summerfield, R.J., P.A. Huxley, P.J. Dart and A.P. Hughes. 1976. Cited by N. Dart et al. In Nitrogen nutrition of cowpea (Vigna unguniculata) II. Effects of short term applications of inorganic nitrogen on growth and yield of nodulated and non-nodulated plants. Expl. Agric. 13:241-252.

Summerfield, R.J., F.R. Minchin and P.A. Huxley. 1977. Plant husbandry and management techniques for growing grain legumes under simulated tropical conditions in controlled environments. Expl. Agric. 13:81-92.

Summerfield, R.J., F.R. Minchin and E.H. Roberts. 1978a. Integrated screening for day length, day and night temperature sensitivity in the onset of flowering and seed yield of soybean and cowpea. Reading Univ. Int. Inst. Trop. Agric. Int. Com., No. 17.

Summerfield, R.J., F.R. Minchin and E.H. Roberts. 1978b. Realization of yield potential in soybean (Glycine max (L.) merr.) and cowpea (*Vigna unguniculata* (L.) Walp). *In* Opportunities for chemical plant growth regulation. Proc. Joint BCPC/BPGRS Symposium. 125-134.

Summerfield, R.J., F.R. Minchin, K.A. Stewart and B.J. Ndunguru. 1977. The effects of day length, day and night temperature on growth, symbiotic nitrogen fixation and seed yield of cowpea cu. K2809 in controlled environments. Reading University: Int. Inst. Trop. Agric. Int. Com. No. 16.

Terman, G.L. 1977. Yield and nutrient accumulation by determinate soybeans as affected by applied nutrients. Agron. J. 69:234-238.

Thomas, C.A., V.L. Miller and R.F. Hill. 1975. Stand loss of soybean from pre-emergence damping off and low temperature imbibition. Plant Disease Reporter. 59:293-296.

Thomas, J.F. and C.D. Raper, Jr. 1976. Photoperiodic control of seed filling for soybeans. Crop Sci. 16:667-672.

Thomas, J.F. and C.D. Raper, Jr. 1977. Marphological response of soybeans as governed by photoperiod, temperature and age at treatment. Bot. Gaz. 138:321-328.

Thomas, J.F. and C.D. Raper, Jr. 1978. Effect of day and night temperatures during floral induction on morphology of soybeans. Agron. J. 6:893-989.

Thompson, L.M. 1970. Weather and technology in the production of soybeans in the central United States. Agron. J. 62:232-236.

Thompson, J.A. 1978. Effect of irrigation interval and plant population on growth, yield and water use of soybeans in a semiarid environment. Austral. J. Expl. Agric. An. Husb. 8:276-281.

Thorton, G.D. 1947. Greenhouse studies of nitrogen fertilization of soybeans and lespedeza using isotope nitrogen. Soil Sci. Soc. Amer. Proc. 11:249-251.

Tsiklauri, A.G. 1975. Consumptive use and productivity of *P. vulgaris* L. Referatiunyizhurnal. 11:456-467.

Van Schaik, P.N. and A.N. Probst. 1958. Effects of some environmental factors on flower production and reproductive efficiency in soybeans. Agron. J. 50:192-197.

Van Schreven, D.A. 1959. Effects of added sugar and nitrogen on nodulation of legumes. Plant and Soil. 1:93-112.

Villiers, V. De. 1975. The effect of high air temperature on the production of four Michigan dry bean cultivars. Crop Production. 4:63-68.

Villiers, V. De, P.C. Nel and R.S. Hammes. 1974. The effect of temperature on the development and reproduction of dry beans, (Phaseolus spp.). Crop Production. 3:7-11.

Wang, L.C., O.J. Attoc and E. Truog. 1953. Effect of lime and fertility levels on the chemical composition and winter survival of alfalfa. Agron. J. 45:381-384.

Wang, J.Y. 1960. A critique of the heat-unit approach to plant response studies. Ecology. 41:785-790.

Wang, J.Y. 1963. The influence of seasonal temperature ranges on pea production. Proc. Amer. Soc. Hort. Sci. 80:436-448.

Weber, C.R. 1966a. Nodulating and non-nodulating soybean isolines II. Response to applied nitrogen and modified soil conditions. Agron. J. 58:46-49.

Weber, C.R. 1966b. Soybean nodules work for you. Iowa Farm Sci. 20:3-5.

Weil, R.R. and A.J. Ohlrogge. 1972. The seasonal development of and effect of interplant competition in soybean nodules. Amer. Soc. Agron. Abst. 39.

Welch, L.D., L.V. Boone, C.G. Chambliss, A.T. Christiansen, D.L. Mulvaney, M.F. Oldham and J.W. Pendleton. 1973. Soybean yields with direct and residual nitrogen fertilization. Agron. J. 65:547-550.

Went, F.W. 1961. Problems in seed viability and germination. Int. Seed Testing Assoc. Proc. 26:674-685.

Whigham, D.K. 1975. International soybean variety experiment. First report of results. INTSOY series No. 8. Univ. of Illinois, Urbana -Champaign. 161p.

Whigham, D.K. 1976. International soybean variety experiment. Second report of results. INTSOY series No. 11. Univ. of Illinois, Urbana-Champaign. 221 p.

Whigham, D.K., N.C. Minor and S.G. Carmer. 1978. Effects of environment and management on soybean performance in the tropics. Agron. J. 70:587-592.

Wiess, M.G., C.R. Weber, S.L. William and A.N. Probst. 1950. Variability of agronomic and seed compositional characters in soybeans as influenced by variety and time of planting. Tech. Bull. U.S. Dept. Agric. No. 1017.

Wilkes, J.M. and D.H. Scarisbrick. 1974. The effect of nitrogenous fertilizer on the seed yield of the navy bean (*Phaseolus vulgaris*). J. Agric. Sci. 83:175-176.

Worley, R.E., D.A. Hegwood and S.A. Harmon. 1971. Cited by R. J. Summerfield et al. 1977. *In* Nitrogen nutrition of cowpea (*Vigna unguniculata*) I. Effects of applied nitrogen and symbiotic nitrogen fixation on growth and seed yield. Expl. Agric. 13:129-142.

Wyatt, J.E. 1977. Seed coat and water absorption properties of seed of near isogenci snap bean lines differing in seed coat color. J. Amer. Soc. Hort. Sci. 102:478-480.

APPENDIX

Table 20. SIMPLE CORRELATION COEFFICIENTS BETWEEN SEVERAL CHARACTERS OF DRY BEAN GENOTYPES PLANTED AT FOUR DIFFERENT DATES.

CHARACTERS^{o}	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. # Pods/Plant	-														
2. # Seeds/Plant	0.31**	-													
3. Weight/100 Seeds	0.26**	0.56**	-												
4. Seed Yield	0.26**	0.54**	0.39**	-											
5. Bilogical Yield	0.15*	0.27**	0.12	0.67**	-										
6. Harvest Index	0.15*	0.44**	0.40**	0.55**	-0.18**	-									
7. Preflowering Phase	0.18*	0.14	-0.01	0.12	0.19**	-0.06	-								
8. # Days to Physiological Maturity	0.05	0.21*	0.17**	0.18**	0.14*	0.05	0.59**	-							
9. Postfloering Phase	-0.11	0.09	0.19**	0.17	-0.03	0.11	-0.41**	0.49**	-						
10. # Nodes/Plant	0.36**	0.21**	0.11	0.39**	0.42**	0.03	0.09	-0.01	-0.08	-					
11. Plant Stand	-0.28**	0.01	0.02	0.19	0.03	0.05	-0.02	-0.09	0.27**	-0.02	-				
12. Plant Height at Flowering	- .09	- .01	.23*	.09	.11	- .02	- .13	.05	.17	- .03	.26**	-			
13. Plant Height at Physiological Maturity	- .01	.22*	.34**	.25**	.15	.12	.37**	.32**	- .02	- .01	- .09	.26**	-		
14. Canopy Width at Flowering	.16	.24**	- .03	.24**	.34**	- .13	.13	.08	.12	.19*	.07	.47**	.24*	-	
15. Canopy Width at Physiological Maturity	.25*	.15	- .02	.23	.29**	- .06	.40**	.17	- .19*	.16	- .21*	- .03	.27**	.37**	-

^{o}Sample size vary with characters.
*, ** Statistically significant at the 5% and 1% probability levels respectively.

Table 21. SIMPLE CORRELATION COEFFICIENTS BETWEEN SEVERAL CHARACTERS OF DRY BEAN GENOTYPES PLANTED AT MAY 19, 1978.

CHARACTERS°	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. # Pods/Plant	-														
2. # Seeds/Pod	0.47**	-													
3. Weight/100 Seeds	0.57**	o.69**	-												
4. Seed Yield	0.15	0.32*	0.32*	-											
5. Biolgical Yield	-0.14	-0.14	-0.16	0.43**	-										
6. Harvest Index	0.24	0.42**	0.47**	0.43**	-0.61**	-									
7. Preflowering Phase	0.22	0.27*	0.24	0.05	-0.15	0.20	-								
8. # Days to Physiological Maturity	0.29*	0.32*	0.39**	0.13	-0.16	0.29*	0.79**	-							
9. Postflowering Phase	0.09	0.08	0.23	0.11	0.01	0.11	-0.44**	0.18	-						
10. # Nodes/Plant	0.07	-0.04	-0.02	0.13	0.11	-0.02	-0.35**	-0.24	0.21	-					
11. Plant Stand	-0.52**	-0.12	-0.18	0.29*	0.39**	-0.14	-0.11	-0.12	-0.02	0.05	-				
12. Plant Height at Flowering	- .13	.04	.09	- .09	- .08	.01	- .12	.05	.18	.17	.21	-			
13. Plant Height at Physiological Maturity	.05	.47**	.44*	.16	- .15	.26	.57**	.54**	- .07	- .26	- .03	.13	-		
14. Canopy Width at Flowering	- .26	.09	- .13	- .01	.09	- .19	- .18	- .10	.09	.12	.51**	.53**	.08	-	
15. Canopy Width at Physiological Maturity	.20	.12	.14	.14	- .11	.24	.09	- .10	- .19	- .29	.01	.29	.11	.04	-

°Sample size vary with characters.
*,** Statistically significant at the 5% and 1% probability levels respectively.

Table 22. SIMPLE CORRELATION COEFFICIENTS BETWEEN SEVERAL CHARACTERS OF DRY BEAN GENOTYPES PLANTED AT MAY 27, 1978.

CHARACTERS[o]	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. # Pods/Plant	-														
2. # Seeds/Pod	-0.24	-													
3. Weight/100 Seeds	-0.20	-0.02	-												
4. Seed Yield	0.17	0.29*	0.23	-											
5. Biological Yield	0.07	0.24	0.32**	0.53**	-										
6. Harvest Index	0.08	-0.02	-0.11	0.28*	-0.61**	-									
7. Preflowering Phase	0.01	-0.20	-0.15	-0.17	-0.03	-0.22	-								
8. # Days to Physiological Maturity	0.13	0.06	0.02	0.17	0.23	-0.15	0.42**	-							
9. Postflowering Phase	0.09	0.25	0.17	0.31*	0.23	0.09	-0.64**	0.43**	-						
10. # Nodes/Plant	0.11	0.08	-0.05	0.23	0.34**	-0.20	-0.23	-0.07	0.17	-					
11. Plant Stand	-0.08	0.23	-0.01	0.21	0.21	-0.08	-0.27*	0.01	-0.27*	0.42**	-				
12. Plant Height at Flowering	.08	.02	.37*	.65**	.56**	- .06	.01	.43*	.38*	.20	.10	-			
13. Plant Height at Physiological Maturity	- .38*	.26	.38*	- .33	- .29	.02	.16	.11	- .05	- .38*	- .12	- .01	-		
14. Canopy Width at Flowering	.24	.33	- .19	.41*	.29	.06	- .18	.29	.44**	.28	.29	.43*	- .13	-	
15. Canopy Width at Physiological Maturity	.04	- .01	- .18	- .32	- .36	- .03	- .04	- .05	- .01	- .01	.15	- .32	- .13	.08	-

[o] Sample size vary with characters.

*,** Statistically significant at the 5% and 1% probability levels respectively.

Table 23. SIMPLE CORRELATION COEFFICIENTS BETWEEN SEVERAL CHARACTERS OF DRY BEAN GENOTYPES PLANTED AT JUNE 7, 1978.

CHARACTERS[o]	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. # Pods/Plant	-														
2. # Seeds/Pod	0.35**	-													
3. Weight/100 Seeds	0.25	0.61**	-												
4. Seed Yield	0.38**	0.54**	0.51**	-											
5. Biological Yield	0.29*	0.25	0.27*	0.69**	-										
6. Harvest Index	0.25	0.52**	0.40**	0.70**	-0.01	-									
7. Preflowering Phase	-0.11	0.10	0.01	-0.05	0.01	-0.07	-								
8. # Days to Physiological Maturity	-0.28*	-0.02	-0.04	-0.21	-0.03	-0.23	0.75**	-							
9. Postflowering Phase	-0.32**	-0.09	-0.04	-0.26*	-0.06	-0.27*	0.29*	0.58**	-						
10. # Nodes/Plant	0.59**	0.42**	0.39**	0.39**	0.39**	0.16	0.01	-0.15	-0.22	-					
11. Plant Stand	0.06	0.31*	0.19	0.36**	0.38**	0.10	-0.07	-0.11	-0.10	0.28*	-				
12. Plant Height at Flowering	- .19	.12	.32	.23	.39*	- .06	.05	- .02	- .08	- .05	.38*	-			
13. Plant Height at Physiological Maturity	- .27	- .01	.28	.22	.10	.14	.17	.15	.10	- .14	.28	.71**	-		
14. Canopy Width at Flowering	.02	.18	.16	.13	.42*	- .16	- .12	- .09	- .01	.13	.47**	.65**	.26	-	
15. Canopy Width at Physiological Maturity	- .05	- .17	- .19	- .26	.03	- .34	- .05	.02	.08	.01	.15	.14	- .09	.63**	-

[o] Sample size vary with characters.

*, ** Statistically significant at the 5% and 1% probability levels respectively.

Table 24. SIMPLE CORRELATION COEFFICIENTS BETWEEN SEVERAL CHARACTERS OF DRY BEAN GENOTYPES PLANTED AT JUNE 15, 1978.

CHARACTERS[o]	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. # Pods/Plant	-														
2. # Seeds/Pod	0.21	-													
3. Weight/100 Seeds	0.17	0.35**	-												
4. Seed Yield	1.11	0.58**	0.49**	-											
5. Biological Yield	.09	0.37**	0.26*	0.76**	-										
6. Harvest Index	.09	0.58**	0.52**	0.79**	0.25*	-									
7. Preflowering Phase	-0.18	-0.07	-0.16	-0.21	-0.27*	-0.01	-								
8. # Days to Physiological Maturity	-0.21	-0.02	-0.01	0.10	-0.02	0.08	0.77**	-							
9. Postflowering Phase	-0.16	0.02	0.10	0.19	0.18	0.13	0.34**	0.86**	-						
10. # Nodes/Plant	0.67**	0.08	0.23	0.13	0.08	0.09	-0.01	0.01	0.01	-					
11. Plant Stand	0.13	0.23	0.09	0.35**	0.31**	0.22	-0.15	0.05	0.19	0.12	-				
12. Plant Height at Flowering	.02	.10	.27	.10	.21	- .08	- .14	- .15	- .10	.04	.01	-			
13. Plant Height at Physiological Maturity	- .03	.01	.35	.27	.31	.11	.01	.21	.31	.05	- .08	.10	-		
14. Canopy Width at Flowering	.24	.08	.05	.15	.41*	- .15	- .05	.04	.11	.15	- .09	- .14	.35*	-	
15. Canopy Width at Physiological Maturity	.21	.26	.09	.45**	.51**	.20	.18	.25	.22	.09	- .02	.09	.26	.49**	-

[o] Sample size vary with characters.

*, ** Statistically significant at the 5% and 1% probability levels respectively.

Table 25. ANALYSIS OF VARIANCE TABLE FOR SEEDLING EMERGENCE AND PLANT STAND.

SOURCE OF VARIANCE	D.F.	MEAN SQUARES		
		7th Day Emergence Count	14th Day Emergence Count	Plant Stand
Replications	3	3566.51	1608.54	1600.33
Planting Dates	3	29208.35**	7733.28**	7525.07**
Error (a)	9	3683.87	700.91	685.71
Fertility Levels	1	1617.04	4.17	25.88
Planting Dates x Fertility Levels	3	162.36	28.39	29.72
Error (b)	12	349.80	102.84	85.21
Genotypes	11	2330.97**	1542.29**	2278.44**
Planting Dates x Genotypes	33	303.14**	115.45	122.44
Fertility Levels x Genotypes	11	110.15	67.82	88.76
Planting dates x Fertility Levels x Genotypes	33	310.25**	97.47	56.30
Error (c)	264	170.50	124.79	98.96

*, ** Statistically significant at the 5% and 1% probability levels respectively.

Table 26. ANALYSIS OF VARIANCE TABLE FOR PREFLOWERING AND POSTFLOWERING PERIOD.

SOURCE OF VARIANCE	D.F.	MEAN SQUARES	
		Preflowering Period	Postflowering Period
Replications	3	17.77*	20.31
Planting Dates	3	757.60**	1097.51**
Error (a)	9	3.26	10.40
Fertility Levels	1	0.17	10.01
Planting Dates x Fertility Levels	3	0.01	1.11
Error (b)	12	0.53	4.95
Genotypes	11	272.20**	64.06**
Planting Dates x Genotypes	33	8.31**	34.42**
Fertility Levels x Genotypes	11	0.45	4.36
Planting Dates x Fertility Levels x Genotypes	33	0.24	2.34
Error (c)	264	0.58	4.52

*, ** Statistically significant at the 5% and 1% probability levels respectively.

Table 27. ANALYSIS OF VARIANCE TABLE FOR HARVEST INDEX, BIOLOGICAL YIELD AND SEED YIELD.

SOURCE OF VARIANCE	D.F.	MEAN SQUARES	
		HARVEST INDEX	SEED YIELD (In Qui/ha)
Replications	3	151.35	601.89
Planting Dates	3	615.12*	3380.37**
Error (a)	9	194.00	181.41
Fertility Levels	1	19.08	52.30
Planting Dates x Fertility Levels	3	106.47	34.97
Error (b)	12	68.93	73.60
Genotypes	11	680.46**	663.55**
Planting Dates x Genotypes	33	255.68**	91.64**
Fertility Levels x Genotypes	11	31.39	5.97
Planting Dates x Fertility Levels x Genotypes	33	58.99	15.73
Error (c)	264	60.31	25.92

*, ** Statistically significant at the 5% and 1% probability levels respectively.

Table 28. ANALYSIS OF VARIANCE TABLE FOR PLANT HEIGHTS AND CANOPY WIDTHS MEASURED AT FLOWERING AND AT PHYSIOLOGICAL MATURITY.

SOURCE OF VARIANCE	D.F.	MEAN SQUARES			
		PLANT HEIGHTS AT FLOWERING	PLANT HEIGHTS AT PHYSIOLOGICAL MATURITY	CANOPY WIDTHS AT FLOWERING	CANOPY WIDTHS AT PHYSIOLOGICAL MATURITY
Replications	1	61.58	96.68	93.81	126.67
Planting Dates	3	436.33*	593.71*	571.51*	505.3*
Error (a)	3	45.51	63.65	60.83	54.25
Fertility Levels	1	25.40	28.3	33.41	38.6
Fertility Levels x Planting Dates	3	18.36	19.8	22.1	29.70
Error (b)	4	24.32	26.81	18.9	31.5
Genotypes	11	153.50**	322.31**	81.42**	70.34**
Planting Dates x Genotypes	33	25.65**	25.91**	29.28**	32.33**
Fertility Levels x Genotypes	11	15.41	21.54*	13.90	12.4
Planting Dates x Fertility Levels Genotypes	33	10.9	13.4	11.55	14.28
Error (c)	88	9.91	11.2	8.6	9.2

*, ** Statistically significant at the 5% and 1% probability levels respectively.

Table 29. ANALYSIS OF VARIANCE TABLE FOR NUMBER OF NODES/PLANT, NUMBER OF PODS/PLANT, NUMBER OF SEEDS/POD AND WEIGHT/100 SEEDS

SOURCE OF VARIANCE	D.F.	NODES/PLANT MEAN SQUARES	D.F.	PODS/PLANT MEAN SQUARES	D.F.	SEEDS/PODS MEAN SQUARES	D.F.	WEIGHT/100 SEEDS MEAN SQUARES
Planting Dates	3	33.89**	3	223.43**	3	5.70**	3	8.69**
Fertility Levels	1	.04	1	10.45	1	0.02	1	1.05
Planting Dates x Fertility Levels	3	10.59	3	10.67	3	0.15	3	0.29
Genotypes	11	277.37**	11	203.49**	11	1.52**	11	119.12**
Planting Dates x Genotypes	33	27.78**	33	10.35	33	0.20	33	1.41**
Fertility Levels x Genotypes	11	5.74	11	20.62*	11	0.27*	11	0.72
Planting Dates x Fertility Levels x Genotypes	33	6.43	33	9.85	33	0.14	33	0.70
Error	255	12.97	233	10.97	229	0.15	259	0.83

*, ** Statistically significant at the 5% and 1% probability levels respectively.

FIGURE 1. Daily air temperatures and rainfall during the growing season 1978 at MSU Experimental Farm.

The line ending with an arrow represents maximum temperature (°C), that with a circle represents minimum temperature (°C). The dotted line represents rainfall.

The shaded area associated with each date represent the initiation of flowering and physiological maturity of dry bean genotypes.

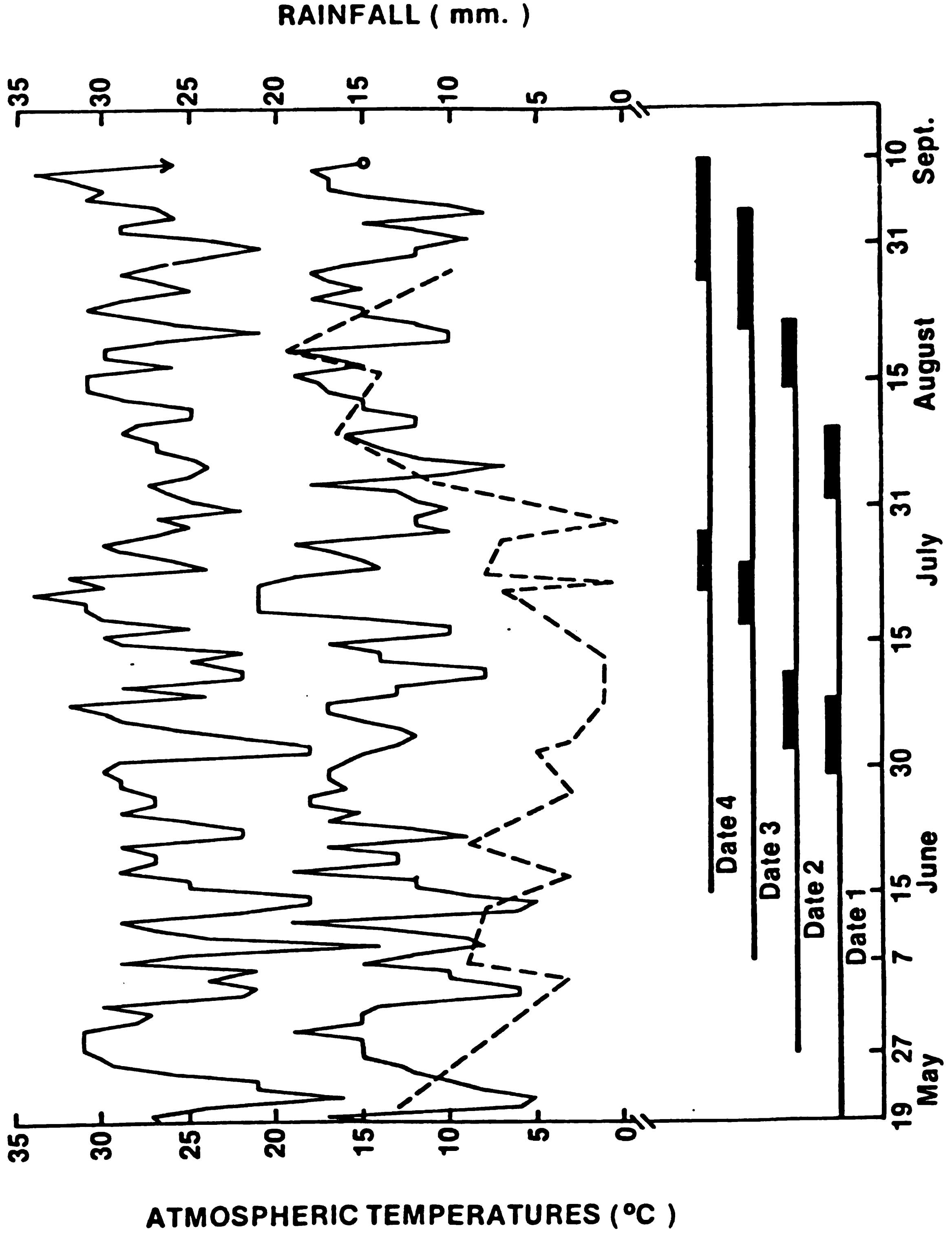

RAINFALL (mm.)
35
30
25
20
15
10
5
0
ATMOSPHERIC TEMPERATURES (°C)
19 May
27
7
15 June
30
15
31 July
15 August
31
10 Sept.
Date 1
Date 2
Date 3
Date 4

FIGURE 1.

FIGURE 2. Average soil temperatures for 5 consecutive days at 10 cms. depth at the experimental site during the growing season, 1978.

The shaded area assoicated with each date represent the initiation of flowering and physiological maturity of dry bean genotypes.

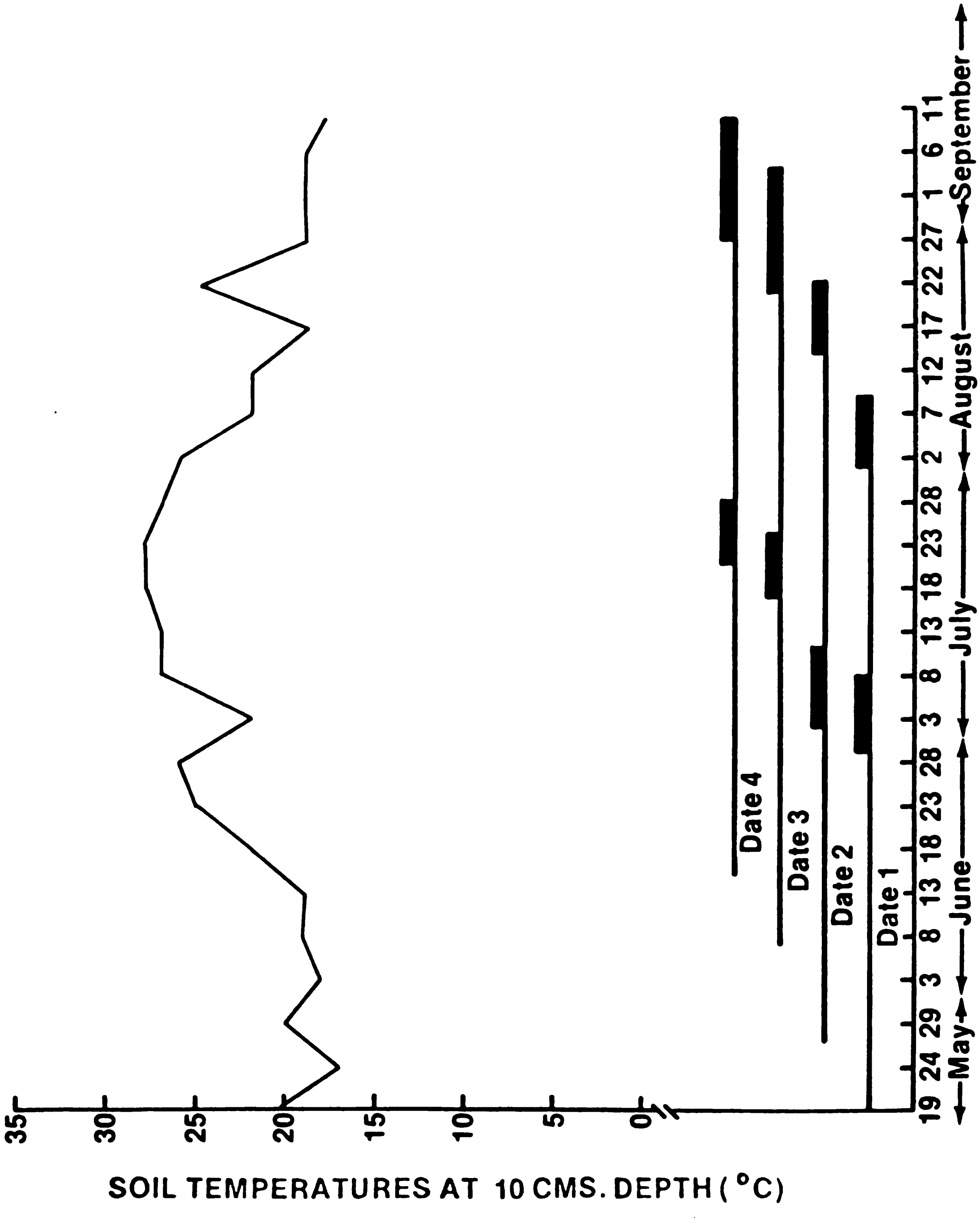

SOIL TEMPERATURES AT 10 CMS. DEPTH (°C)
35
30
25
20
15
10
5
0
19
24
29
3
8
13
18
23
28
3
8
13
18
23
28
2
7
12
17
22
27
1
6
11
May
June
July
August
September
Date 1
Date 2
Date 3
Date 4

FIGURE 2.

FIGURE 3A. Seedling emergence (%) at 7th day from each planting date of Rico-23 and Viva (Pink) at the fertility levels.

The solid line represents seedling emergence at normal fertility level while the dotted line represents seedling emergence at plots that received additional Potassium.

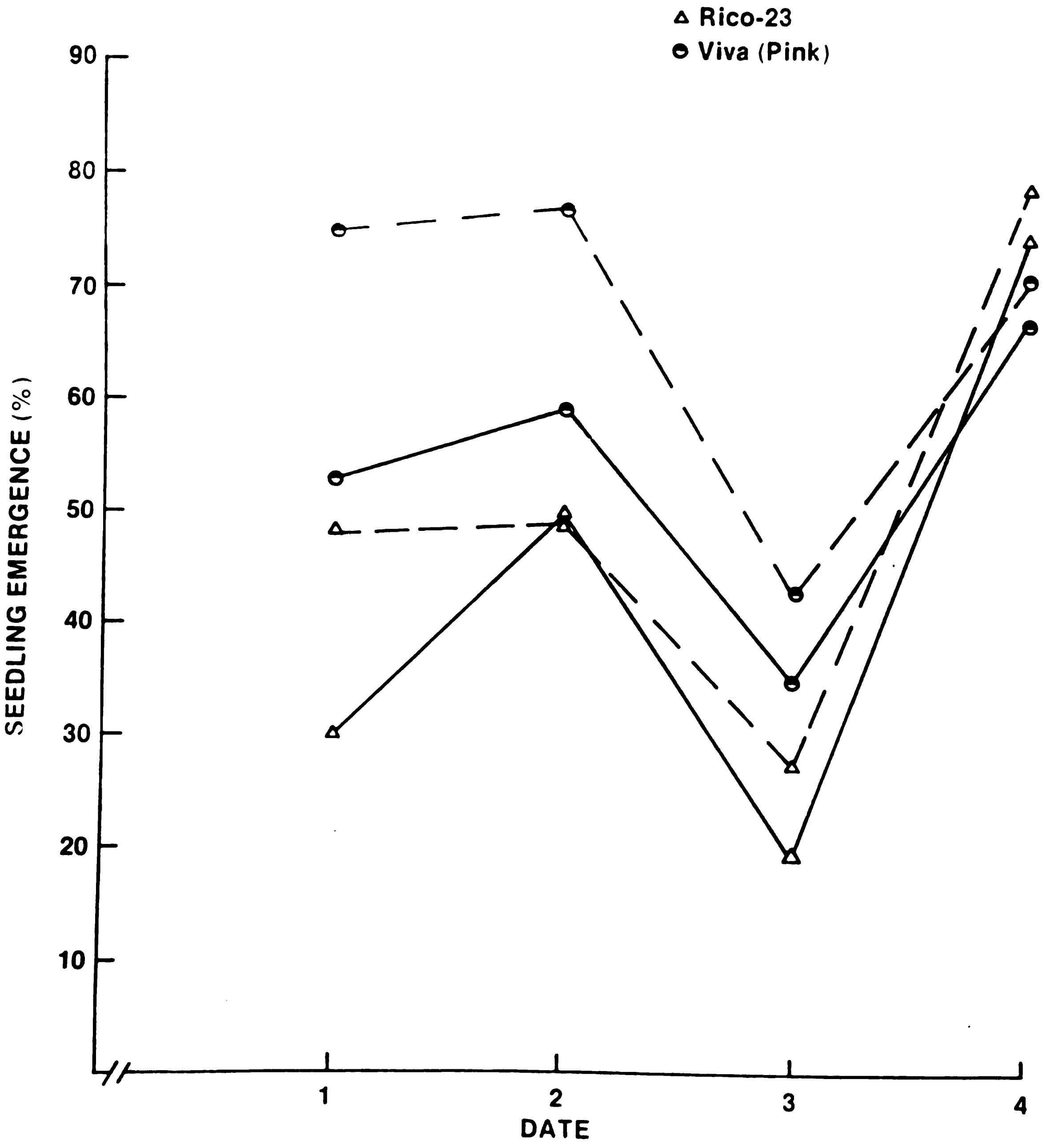

△ Rico-23
● Viva (Pink)
90
80
70
60
50
40
30
20
10
SEEDLING EMERGENCE (%)
1
2
3
4
DATE

FIGURE 3A.

FIGURE 3B. Seedling emergence (%) at 7th day from each planting date of Tuscola and Strain No. 20489 at the two fertility levels.

The solid line represents seedling emergence at normal fertility level while the dotted line represents seedling emergence at plots that received additional Potassium.

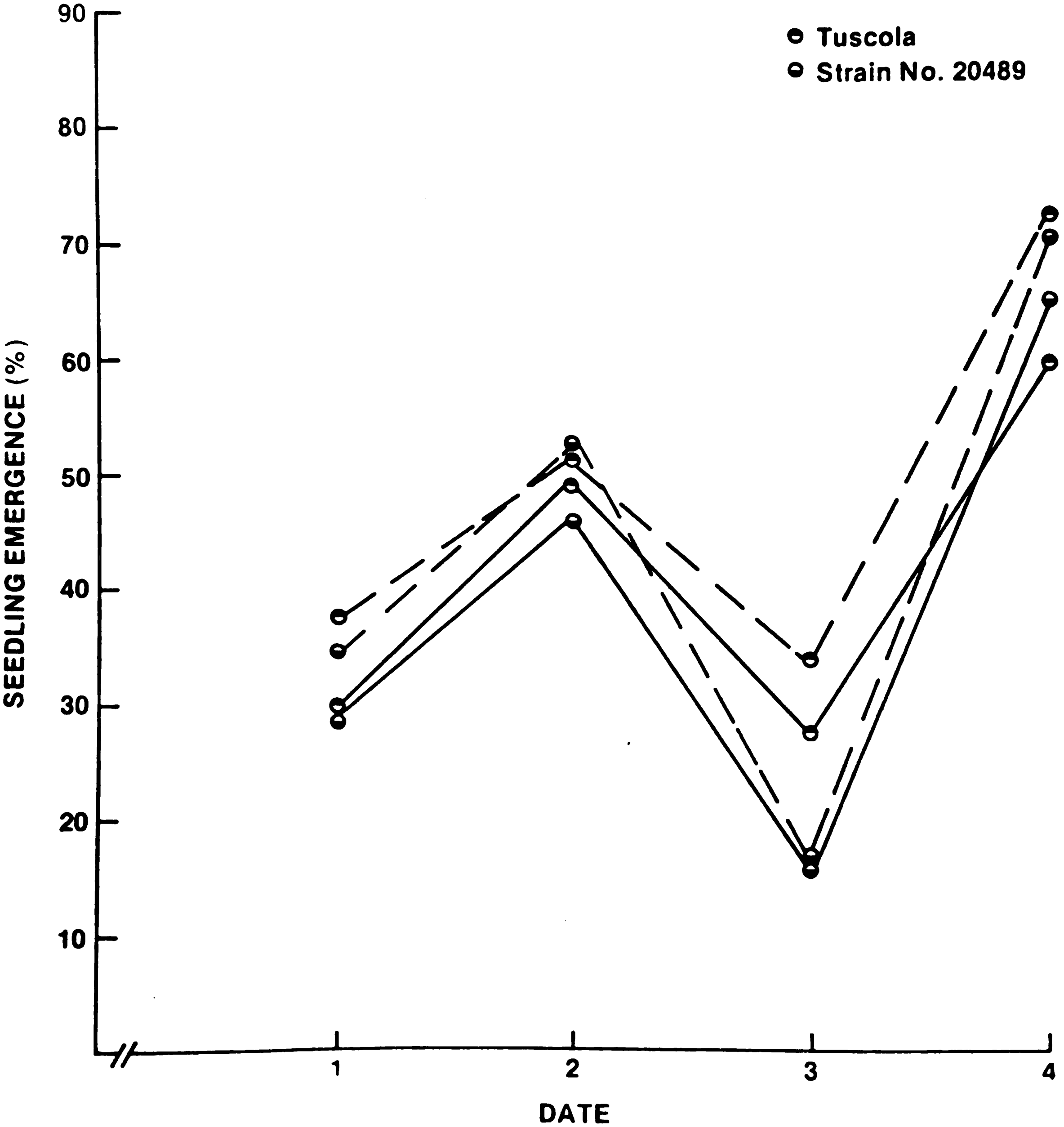

Tuscola
Strain No. 20489
SEEDLING EMERGENCE (%)
90
80
70
60
50
40
30
20
10
DATE
1
2
3
4

FIGURE 3B.

FIGURE 3C. Seedling emergence (%) at 7th day from each planting date of Sanilac and Seafarer at the two fertility levels.

The solid line represents seedling emergence at normal fertility level while the dotted line represents seedling emergence at plots that received additional Potassium.

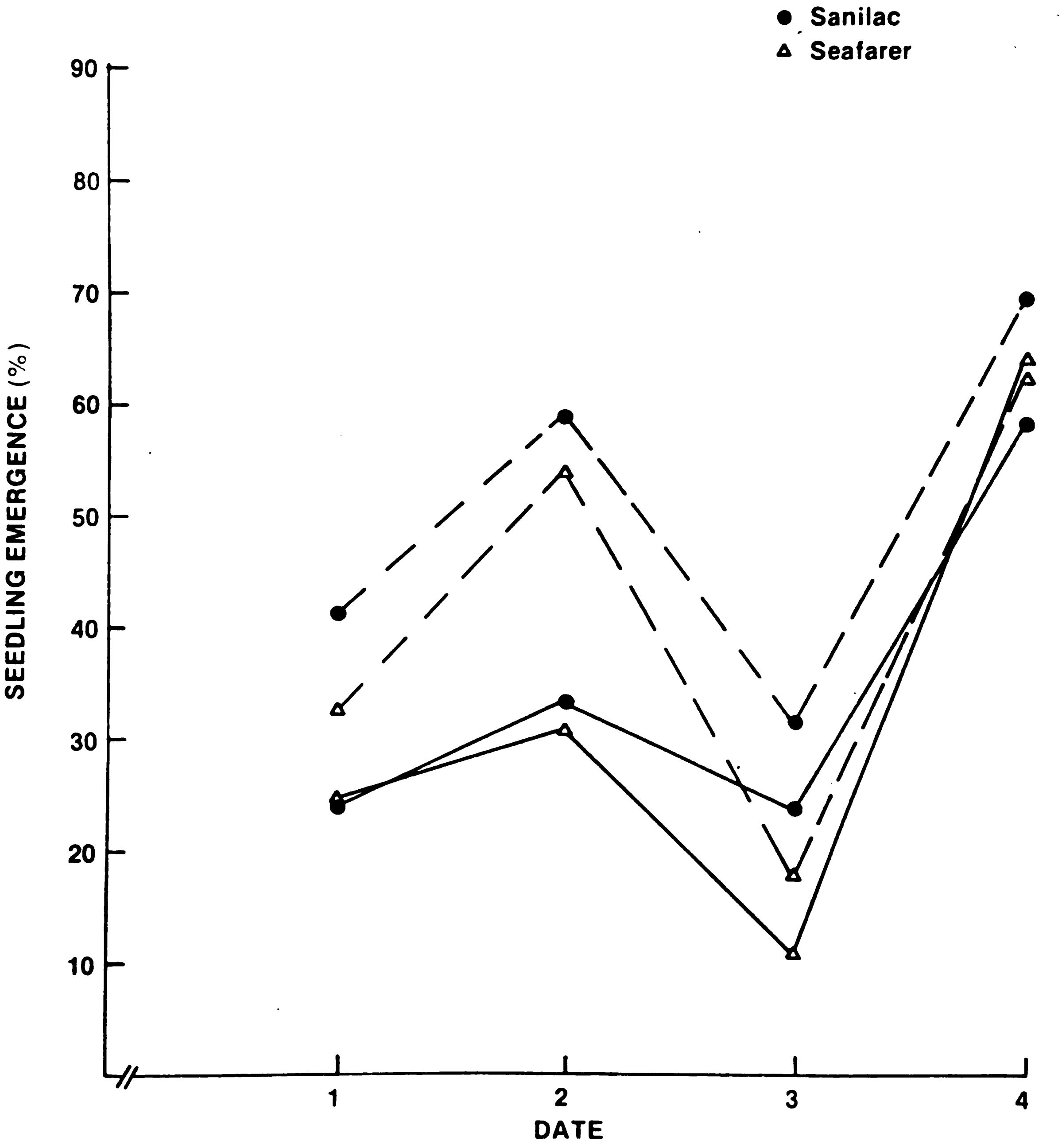

● Sanilac
△ Seafarer
SEEDLING EMERGENCE (%)
90
80
70
60
50
40
30
20
10
1
2
3
4
DATE

FIGURE 3C.

FIGURE 3D. Seedling emergence (%) at 7th day from each planting date of Aurora and P.I. 165426 (White) at the two fertility levels.

The solid line represents seedling emergence at normal fertility level while the dotted line represents seedling emergence at plots that received additional Potassium.

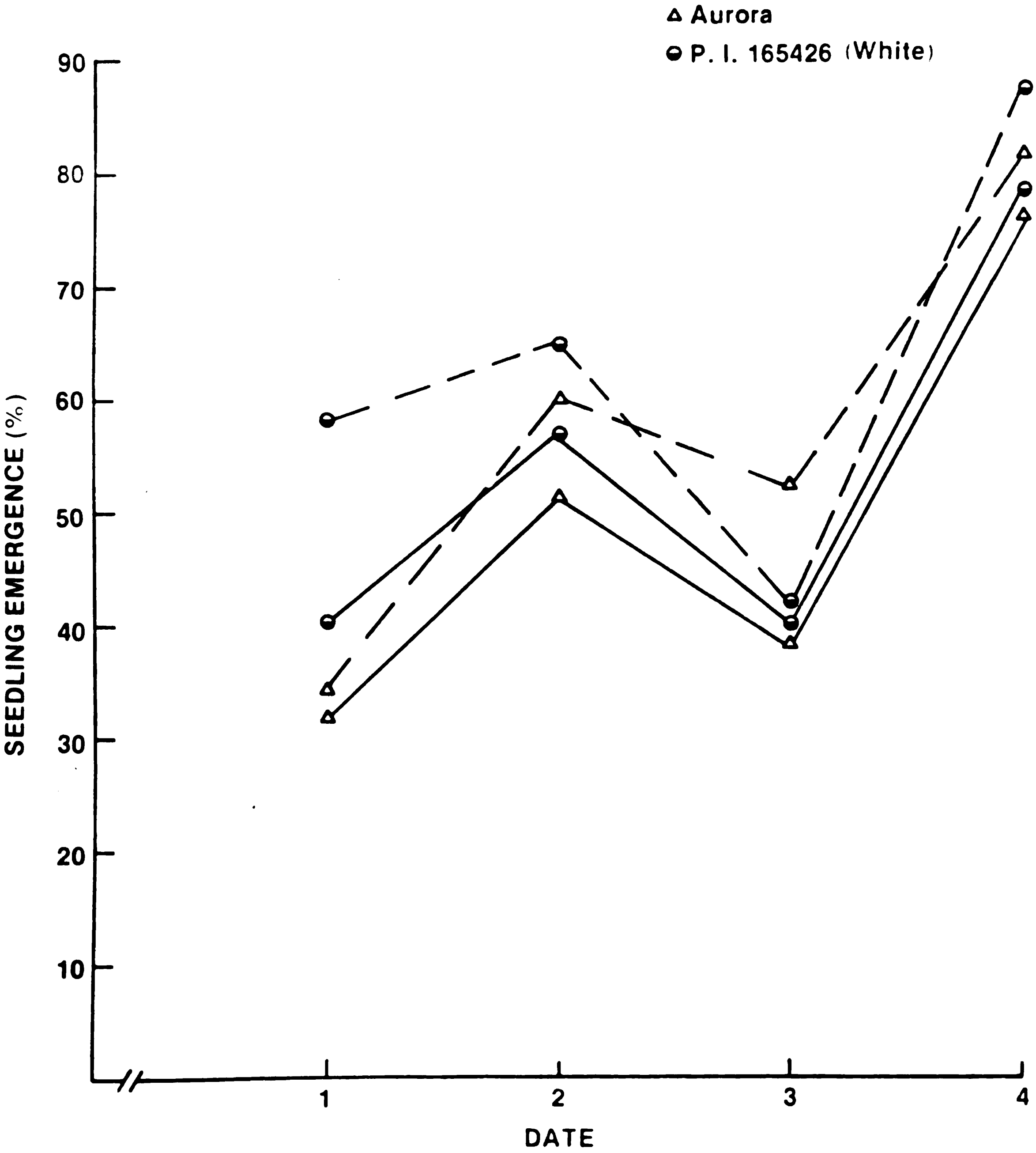

△ Aurora
● P. I. 165426 (White)
SEEDLING EMERGENCE (%)
90
80
70
60
50
40
30
20
10
1
2
3
4
DATE

FIGURE 3D.

FIGURE 3E. Seedling emergence (%) at 7th day from each planting date of Ex-Rico-23 and Viva (White) at the two fertility levels.

The solid line represents seedling emergence at normal fertility level while the dotted line represents seedling emergence at plots that received additional Potassium.

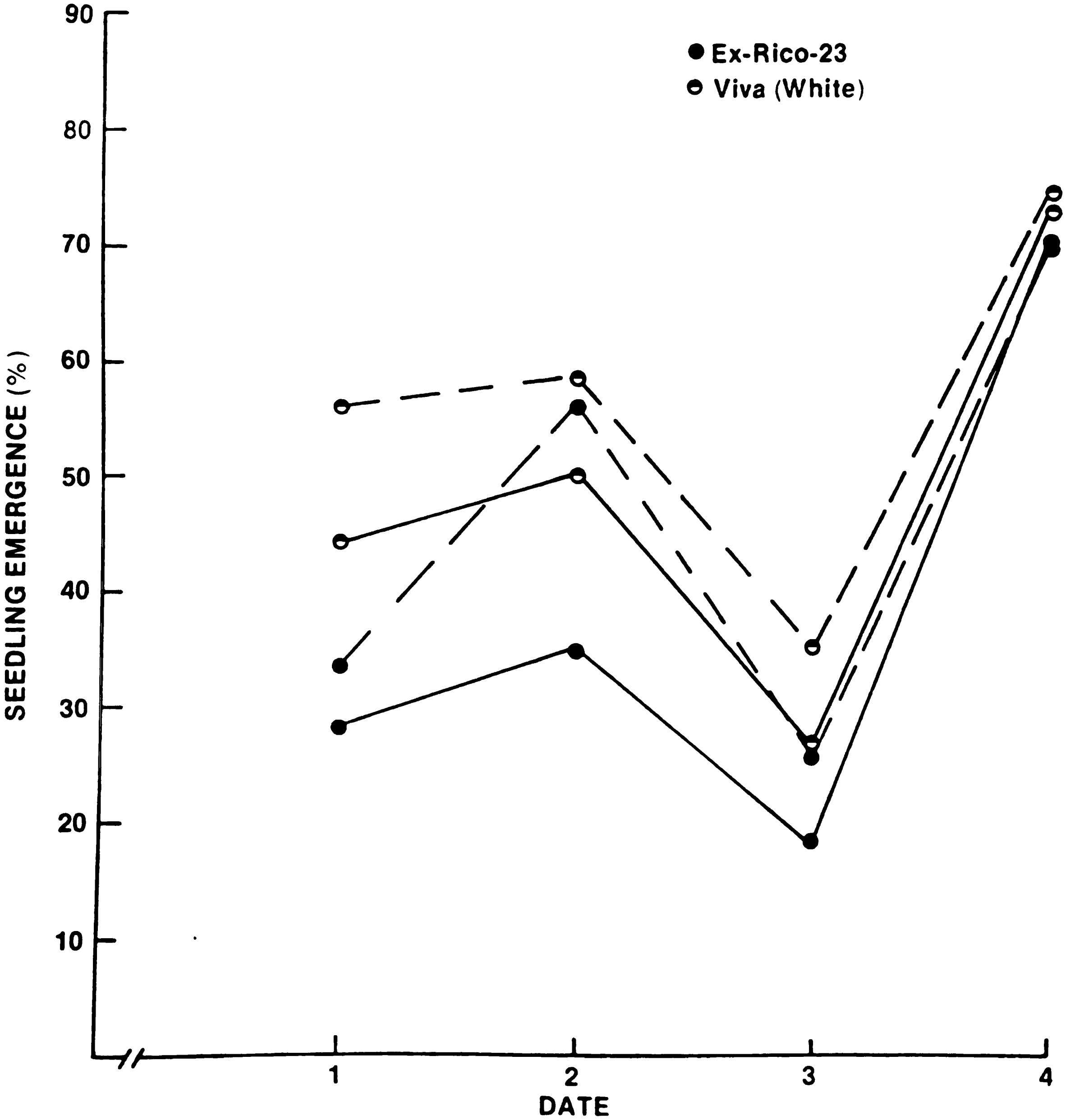

● Ex-Rico-23
○ Viva (White)
SEEDLING EMERGENCE (%)
90
80
70
60
50
40
30
20
10
1
2
3
4
DATE

FIGURE 3E.

FIGURE 3F. Seedling emergence (%) at 7th day from each plantind date of Black Turtle Soup and P.I. 165426 (Black) at the two fertility levels.

The solid line represents seedling emergence at normal fertility level while the dotted line represents seedling emergence at plots that received additional Potassium.

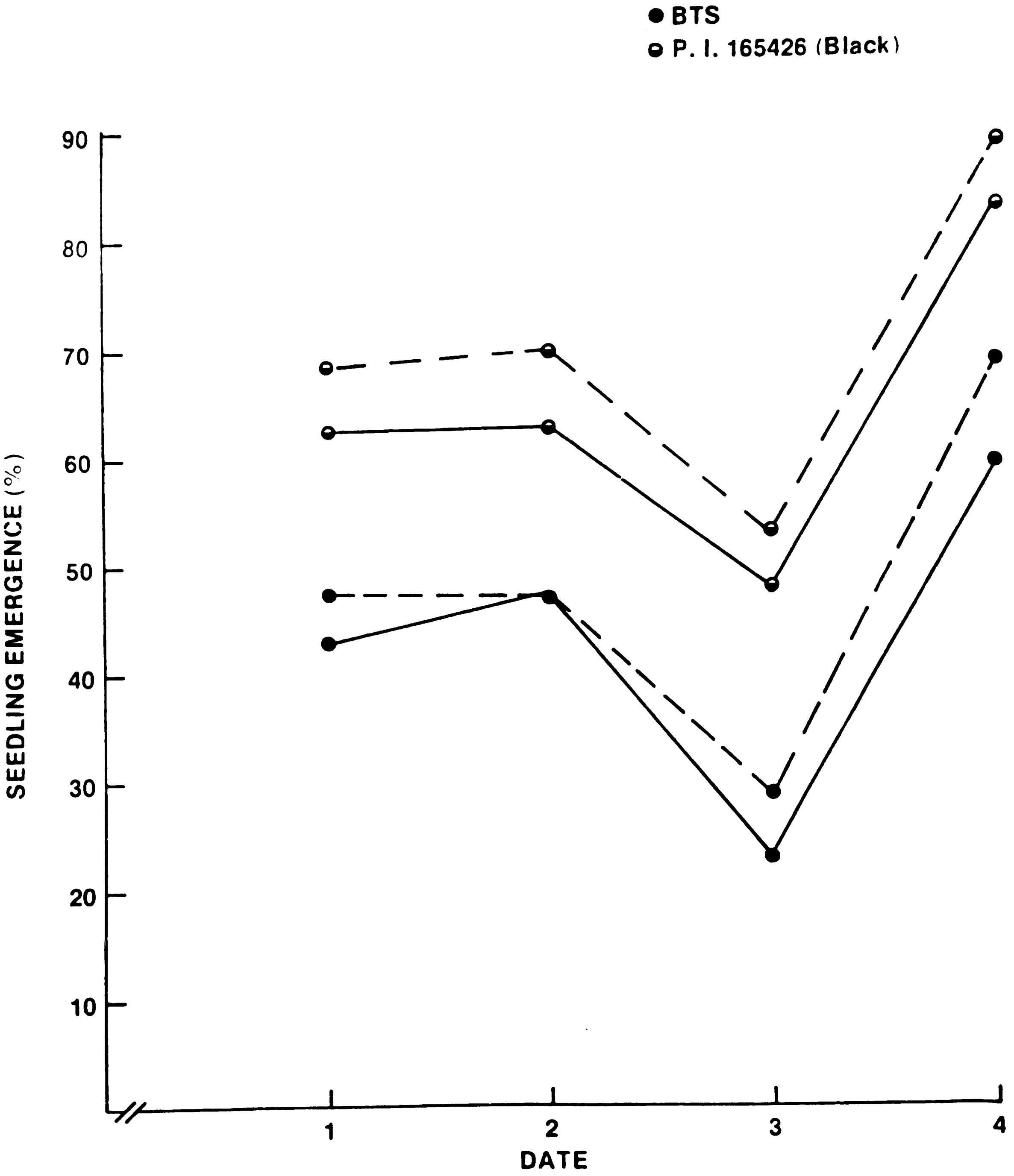

● BTS
○ P. I. 165426 (Black)
SEEDLING EMERGENCE (%)
90
80
70
60
50
40
30
20
10
1
2
3
4
DATE

FIGURE 3F.

FIGURE 4A. Plant stand (%) of Black Turtle Soup, Rico-23, Ex-Rico-23, and Aurora at each planting date.

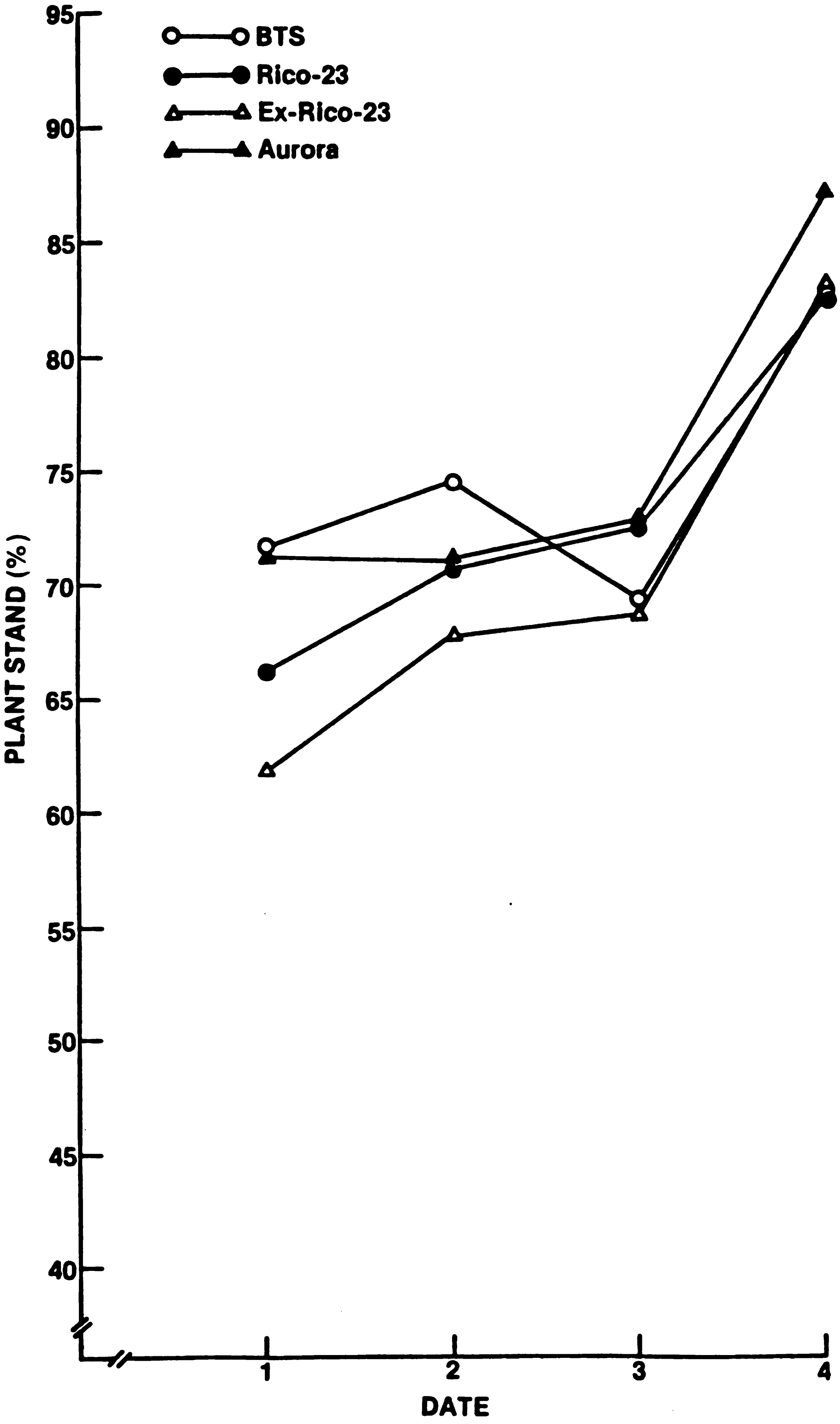
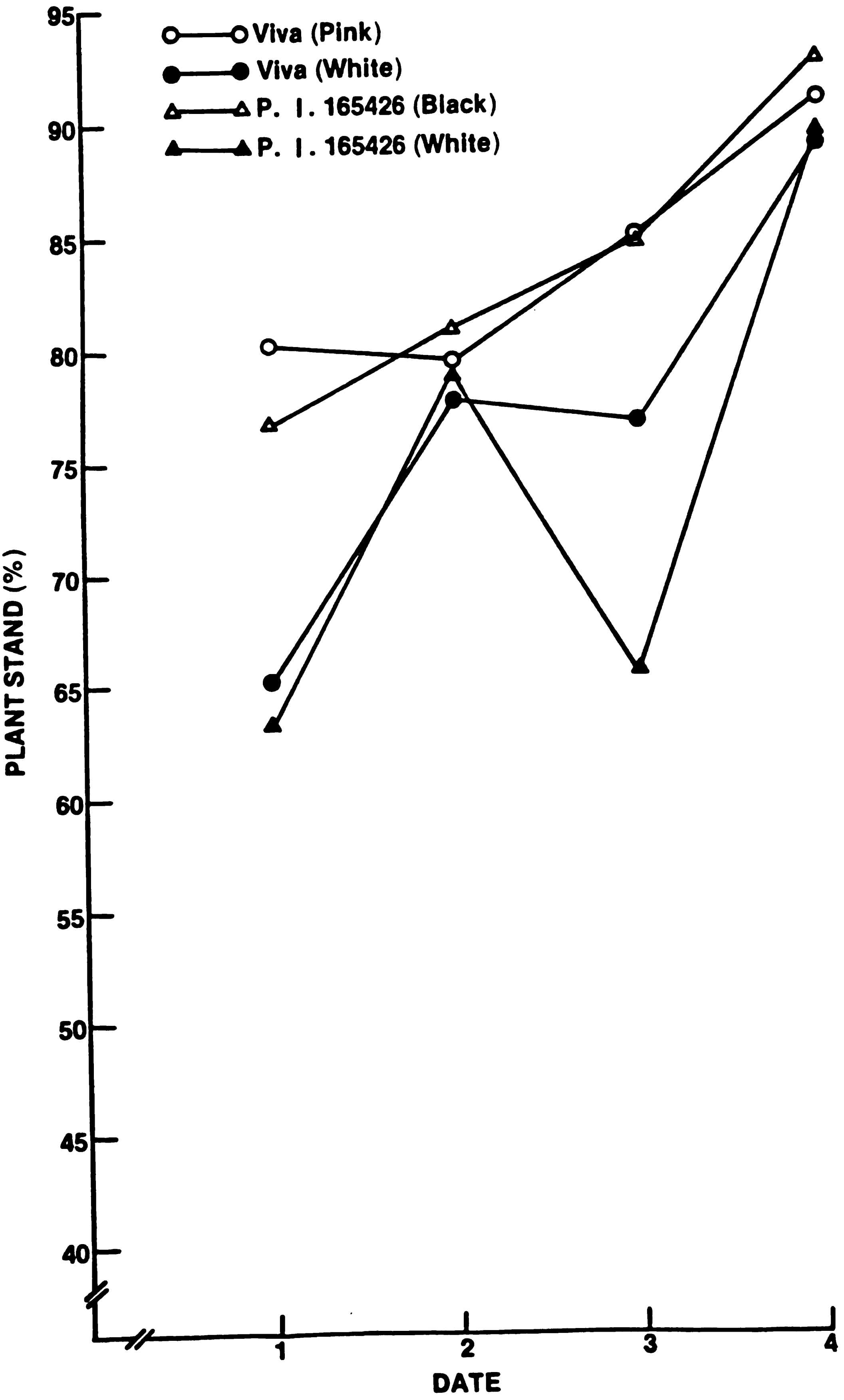

BTS
Rico-23
Ex-Rico-23
Aurora
PLANT STAND (%)
95
90
85
80
75
70
65
60
55
50
45
40
DATE
1
2
3
4

FIGURE 4A.

FIGURE 4B. Plant stand (%) of Viva (Pink), Viva (White), P.I. 165426 (Black) and P.I. 165426 (White) at each planting date.



Viva (Pink)
Viva (White)
P. I. 165426 (Black)
P. I. 165426 (White)
PLANT STAND (%)
95
90
85
80
75
70
65
60
55
50
45
40
1
2
3
4
DATE

FIGURE 4B.

FIGURE 4C. Plant stand (%) of Sanilac, Seafarer, Tuscola and Strain No. 20489 at each planting date.

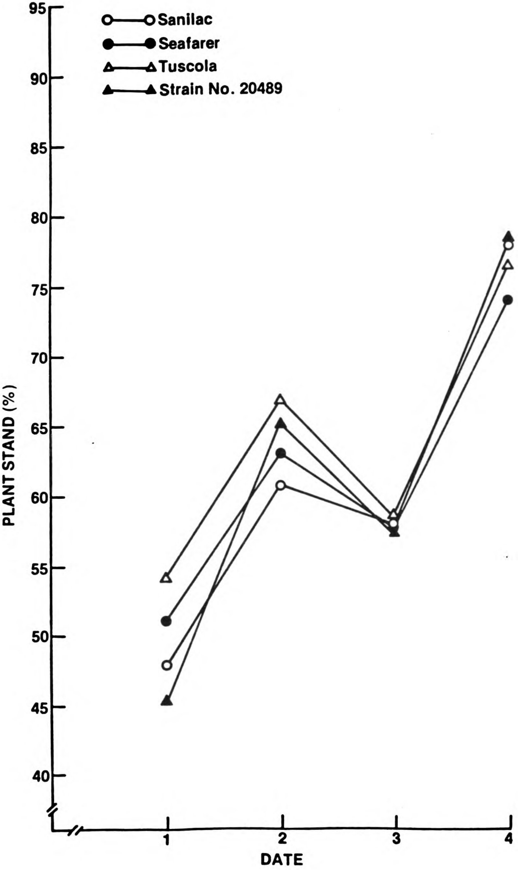

Sanilac
Seafarer
Tuscola
Strain No. 20489
95
90
85
80
75
70
65
60
55
50
45
40
PLANT STAND (%)
1
2
3
4
DATE

FIGURE 4C.

FIGURE 5A. Seed yield (Qui/ha) of Rico-23, Aurora, Viva (Pink) and Viva (White) at each planting date.

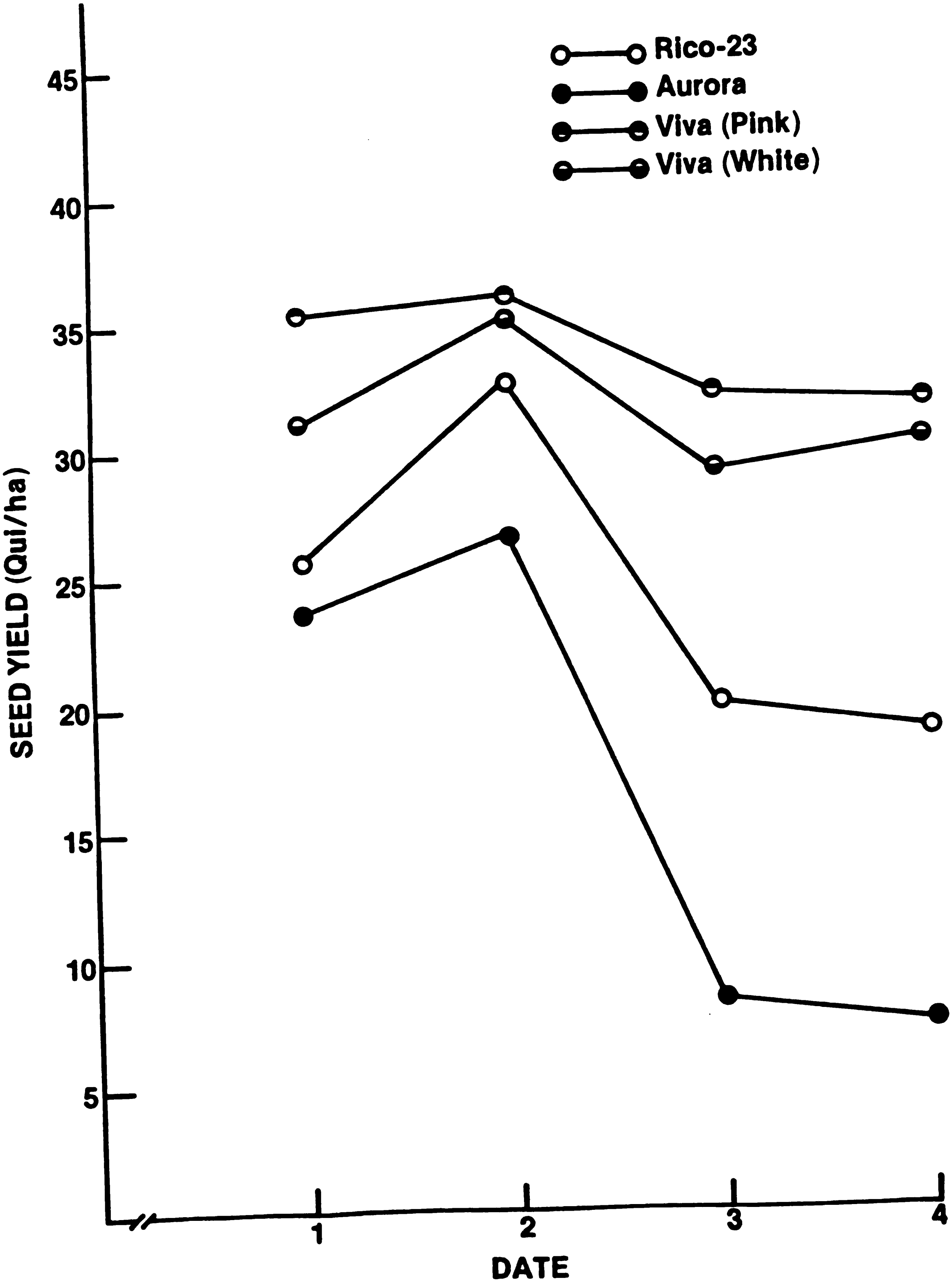

Rico-23
Aurora
Viva (Pink)
Viva (White)
SEED YIELD (Qui/ha)
45
40
35
30
25
20
15
10
5
1
2
3
4
DATE

FIGURE 5A.

FIGURE 5B. Seed yield (Qui/ha) of Sanilac, Seafarer, Tuscola and Strain No. 20489 at each planting date.

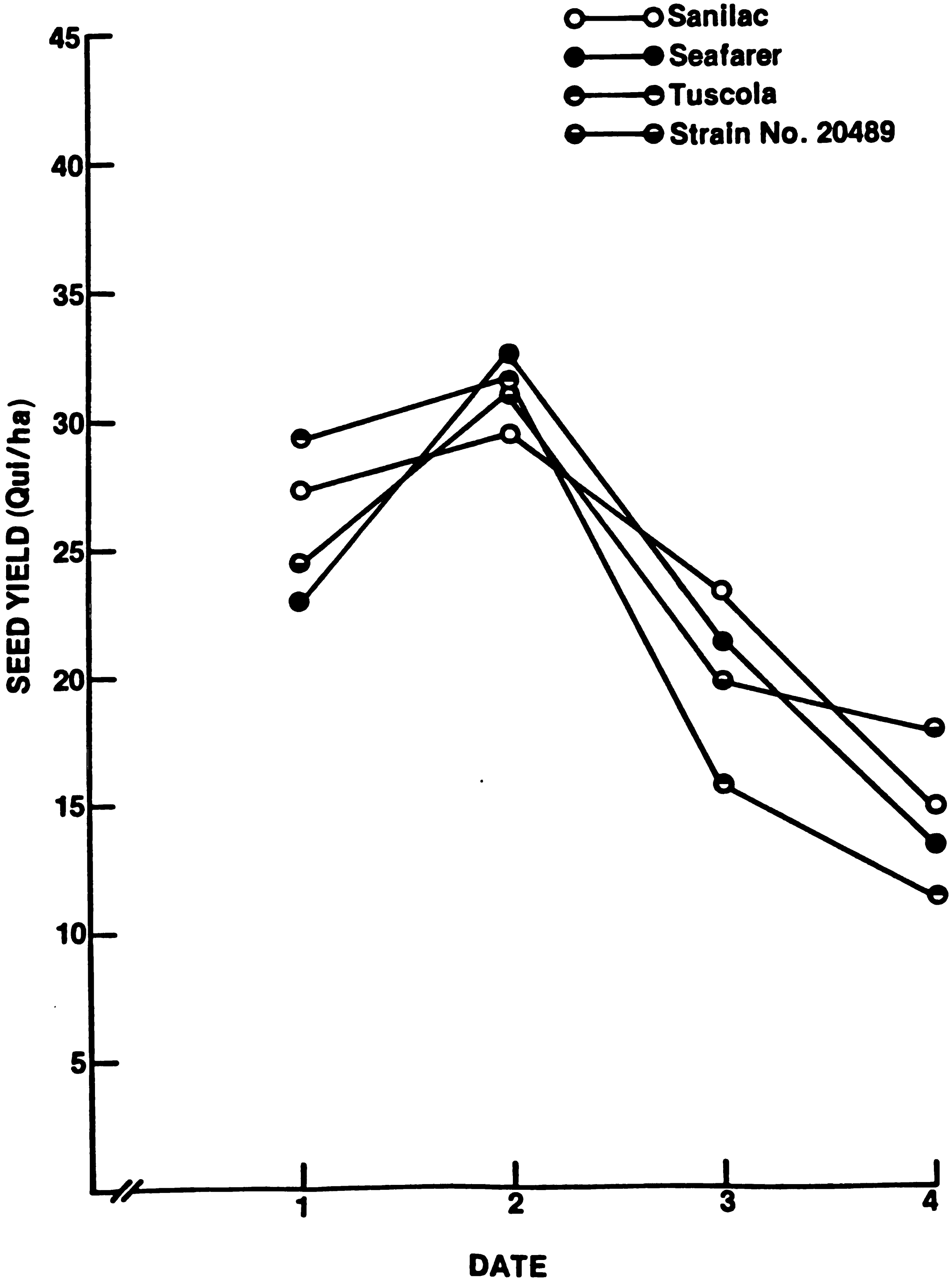

Sanilac
Seafarer
Tuscola
Strain No. 20489
SEED YIELD (Qui/ha)
45
40
35
30
25
20
15
10
5
1
2
3
4
DATE

FIGURE 5B.

FIGURE 5C. Seed yield (Qui/ha) of Black Turtle Soup, P.I. 165426 (White), P.I. 165426 (Black) and Ex-Rico-23 at each planting date.

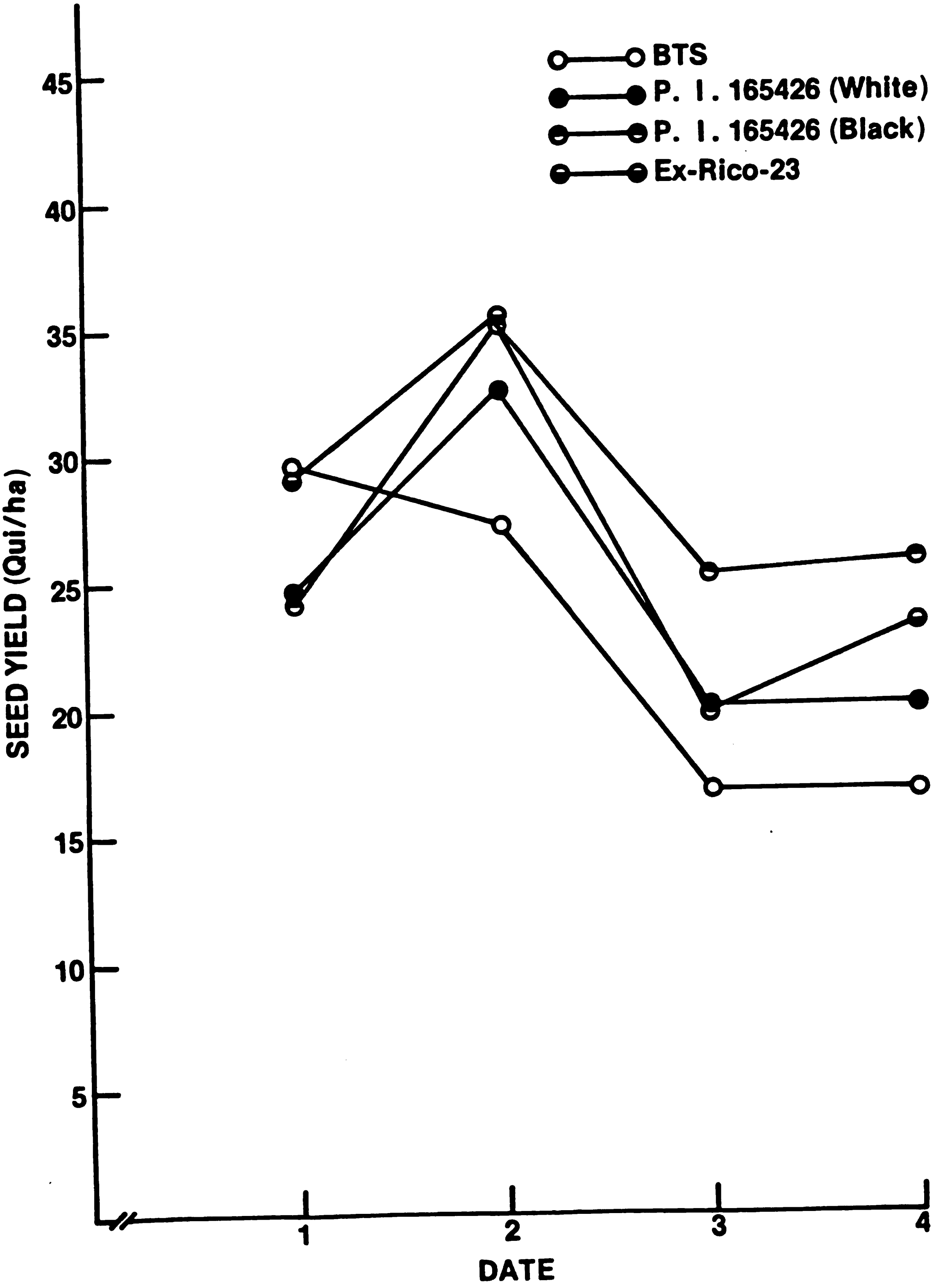

BTS
P. I. 165426 (White)
P. I. 165426 (Black)
Ex-Rico-23
SEED YIELD (Qui/ha)
45
40
35
30
25
20
15
10
5
1
2
3
4
DATE

FIGURE 5C.

FIGURE 6A. Harvest Index (%) of Black Turtle Soup, Rico-23, and P.I. 165426 (Black) at each planting date.

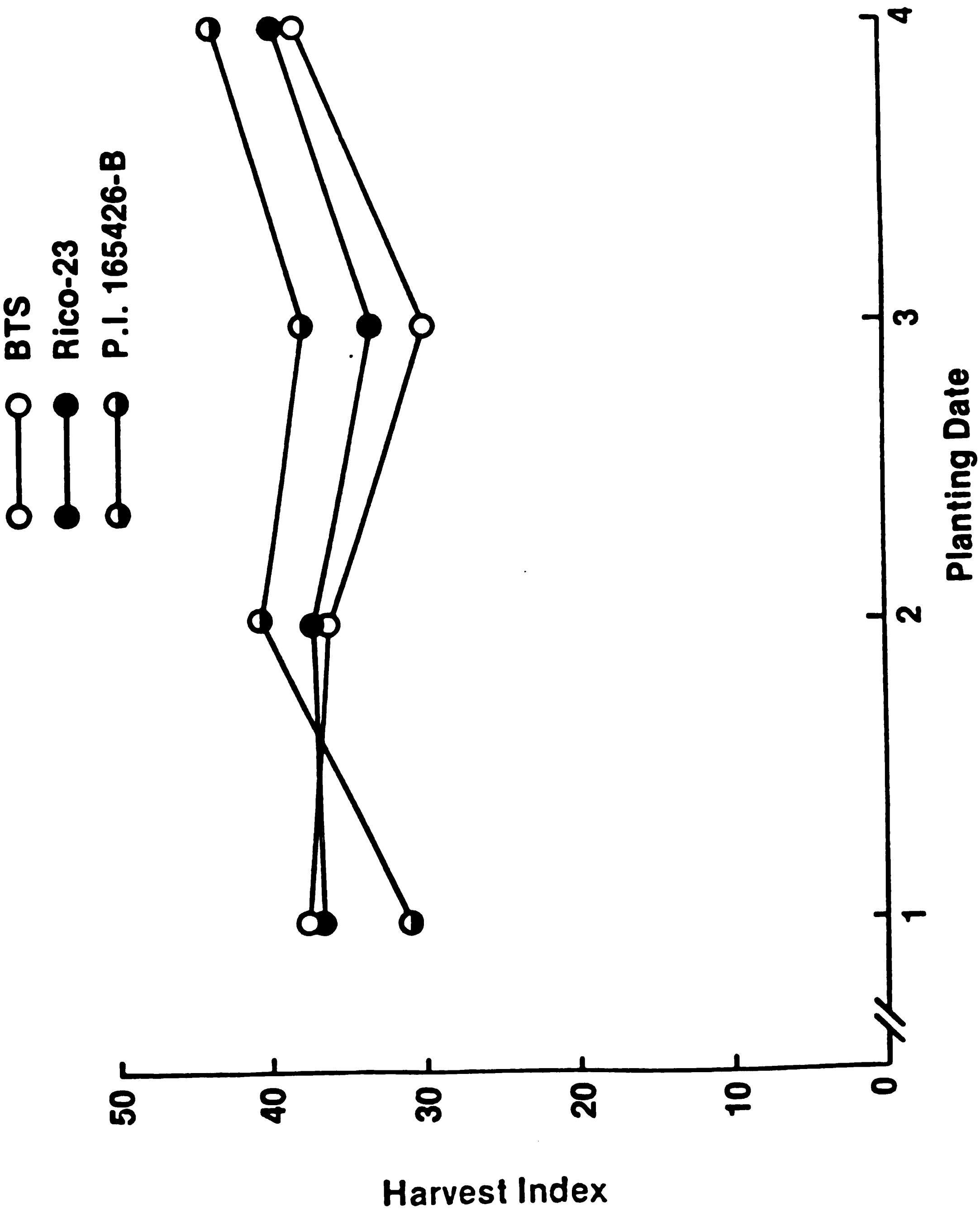

BTS
Rico-23
P.I. 165426-B
Harvest Index
50
40
30
20
10
0
Planting Date
1
2
3
4

FIGURE 6A.

FIGURES 6B. Harvest Index (%) of Sanilac, Seafarer, Tuscola and Strain No. 20489 at each planting date.

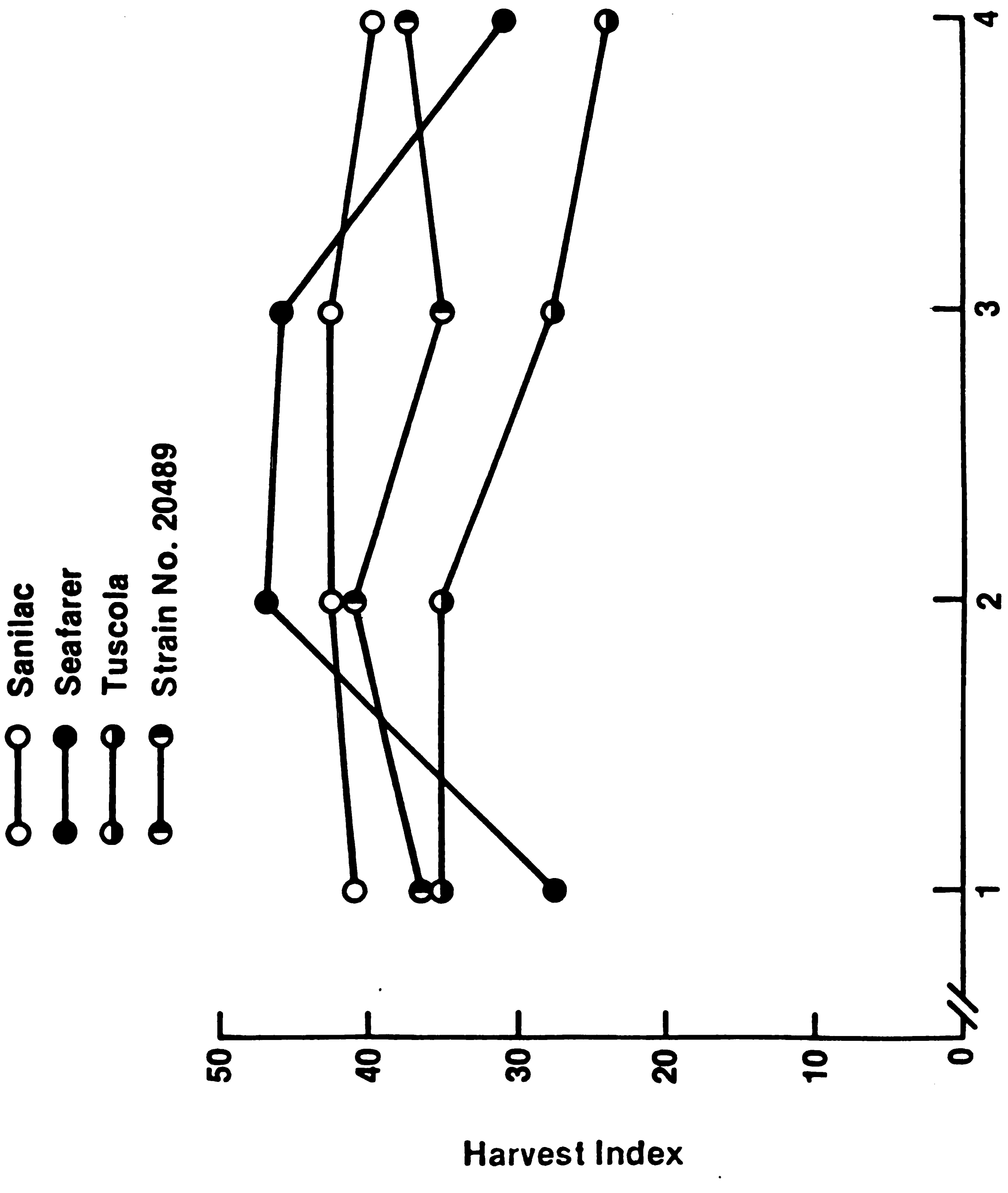

Sanilac
Seafarer
Tuscola
Strain No. 20489
Harvest Index
0
10
20
30
40
50
Date
1
2
3
4

FIGURE 6B.

FIGURE 6C. Harvest Index (%) of Viva (Pink), Viva (White), Ex-Rico-23, Aurora and P.I. 165426 at each planting date.

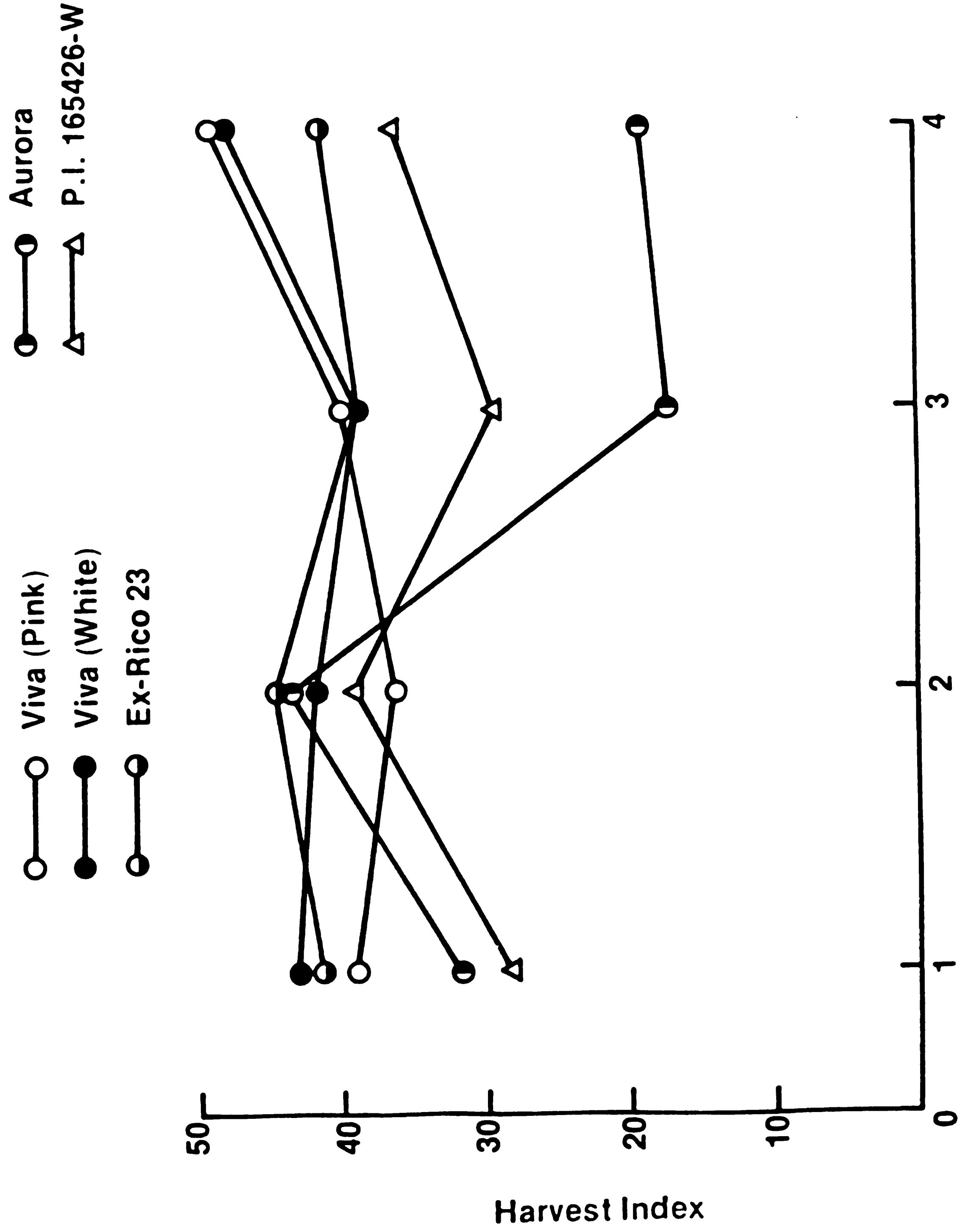

Viva (Pink)
Viva (White)
Ex-Rico 23
Aurora
P.I. 165426-W
Harvest Index
50
40
30
20
10
0
1
2
3
4
Date

FIGURE 6C.